

UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
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BIOLOGY AND CONTROL
OF CITRUS INSECTS
AND MITES

H. J. QUAYLE

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BIOLOGY AND CONTROL OF CITRUS INSECTS AND MITES^{1, 2, 3}

H. J. QUAYLE⁴

Earlier bulletins published by the University of California on citrus insects have been out of print for several years, and the aim of the present publication is to replace in part those earlier bulletins, for which there has been a constant demand, as well as to bring the subject of citrus-insect control in California up to date. Since many of the requests call for detailed information on the biology of the pests, and because such information is least available, it seems desirable to cover that phase of the subject as adequately as the limited space in this publication will allow.

The order of discussion of the pests is more or less in accordance with their classification as they occur in the animal kingdom, and not necessarily in accordance with their relative importance as pests of citrus.

Upon such cultural operations as cultivation, fertilization, and irrigation, the California citrus grower is usually well posted; he is personally interested in them, and has a program for them; many growers, however, are not so much interested in their pest-control requirements. This is probably natural enough, because they have depended rather too much upon county, state, and government officials, and other agencies, for their information, and upon having the control work done largely by others. It is hoped that this bulletin will enable the growers to become somewhat better acquainted with the pests and to stimulate a more active interest in the actual handling of the pests on their own properties.

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³ Only California insects (and mites) are included in this bulletin, except that a brief discussion is given of the Mediterranean fruit fly and the Mexican fruit fly, which do not occur in the state; and the white fly, which, while it occurs in the state, has not become established in commercial citrus plantings.

⁴ Professor of Entomology and Entomologist in the Experiment Station.

KEY TO THE COMMON CITRUS-INFESTING INSECTS AND MITES⁵

For those not familiar with the use of a key, it should perhaps be explained that each of the two main divisions is in turn divided into several parts indicated by capital letters. In all subdivisions of these parts, two (or at most three) sets of contrasting characteristics are described, one under a single letter, such as *a*, and its opposite under a doubling of the same letter, such as *aa*. An insect is identified by a process of elimination. The insect is examined for one set of characteristics at a time, and parts of the key that do not fit are systematically eliminated. It is necessary to decide first whether the insect belongs under *A*, *B*, *C*, or *D*, etc., than whether, under the particular division chosen, the insect belongs under *a* or *aa*. Subdivisions *b* and *bb* will be found under each of these, and the correct one must be selected before proceeding to the choice between *c* and *cc*, etc.

The use of the key can best be shown by an example: Suppose the insect to be identified has been found on the surface of the fruit; this eliminates all insects listed under *B*, *C*, and *D*, which are found on other parts of the tree, and narrows the search to those listed under *A*. Since the insect was found on the outside of the fruit, it will be found under *a* rather than under *aa* (page 6). The body of the insect is found to be covered with a white powder, so that it will be under *b* rather than under *bb* (page 5). The insect has wings, also covered with a white powder; this eliminates *c*; under *cc* no further subdivisions of the key are given, and the name "citrus white fly" is found. The identification can be verified by the description of the insect in the body of the text.

I. Identification by general appearance of the insects and mites: entire life spent on plant; insects clearly associated with the injury they do

A. Infesting or occurring on fruit

a. On surface of fruit

b. Body of insects covered with white mealy powder

c. Wingless; slightly active; variable in size; ranging to $\frac{3}{16}$ inch in length; adults with cottony egg masses adhering.....*Mealybugs*

d. Posterior filaments usually as long as or longer than the body
.....Long-tailed mealybug

dd. Posterior filaments shorter than the body

e. Body fluids yellow or orange in color

f. Posterior and lateral filaments short and stubby.....*Citrus mealybug*

ff. Posterior and lateral filaments longer than in *f* and slender.....*Baker's mealybug*

⁵ The author is indebted to Mr. Harold Compere for the general arrangement of this key.

- ee. Body fluids of a claret color
 - f. Posterior and lateral filaments short and stubby Japanese mealybug
 - ff. Two posterior filaments longer and tapering Citrophilus mealybug
- cc. Winged; delicate; $\frac{1}{16}$ inch in length; flying readily when disturbed; wings, as well as body, covered with fine white powder Citrus white fly, adults
- bb. Body of insects not covered with white powder or wax
 - c. Removable (usually) hard shell or scale covering, soft sac-like, yellow or whitish bodies; shells circular or elongate; legs and antennae lacking; firmly attached to plant by thread-like beak inserted into the tissue Armored or diaspine scales
 - d. Circular species
 - e. Scales or covering grayish in color
 - f. Flattened, smooth, light to dark gray in color, exuvia (cast skins) nearly central Ivy or oleander scale
 - ff. Convex, pointed, light gray in color, exuvia a trifle closer to the side than in the preceding species; waxy covering thin, partially revealing the yellow sac-like body beneath Greedy scale
 - ee. Scales or covering red or yellow in color
 - f. Red in color, infesting twigs and hard wood as well as the leaves and fruits Red scale
 - ff. Yellow in color, only occasionally on wood, mostly on fruit and leaves Yellow scale
 - dd. Elongate, narrow, more or less curved, resembling a narrow oyster shell, purplish-brown in color
 - e. Usually somewhat curved, common species Purple scale
 - ee. Like the foregoing but narrower and straighter..Glover's scale
- cc. Not covered with a hardened, detachable scale
 - d. $\frac{1}{200}$ of an inch, just visible to the unaided eye; associated with silvering of lemons in San Diego County Silver or rust mite
 - dd. Very small insects or mites ranging from $\frac{1}{40}$ to $\frac{1}{60}$ of an inch in size, plainly visible to the unaided eye
 - e. Winged individuals never present; body not divided into head, thorax, and abdomen; with 4 pairs of legs (3 pairs in young) Mites or spiders
 - f. Dark red in color; the back with white bristles projecting from prominent tubercles; eggs with radiating guy threads from vertical stalks Citrus red spider
 - ff. Light pink to greenish-yellow, sometimes with dark markings; main colonies confined to pale yellow depressions on the underside of leaves Six-spotted mite

- e. Transparent, pale, $\frac{1}{30}$ of an inch in diameter, on under sides of leaves only; associated with minute ($\frac{1}{100}$ inch) cream-colored eggs, and at certain times with mealy-winged adults
.....Citrus white fly, larva
- ee. Semitransparent or opaque, mottled with gray or brown.....
.....*Immature unarmored or lecanine scales*
- f. With indications of a raised H on the back, opaque, brown to black.....Black scale
- ff. Skin slightly rough but without a distinct raised H on the back; mottled gray or brown, semitransparent
 - g. Infestation usually restricted to single branches or individual trees; individuals of different sizes.....
.....Soft brown scale
 - gg. Infestation generally distributed, individuals of same sizeCitricola scale
- dd. Body soft; legs and antennae visible
 - e. Body slightly flattened, slender, active insects readily crawling; adults with fringed wings; associated with deformed leaves, thickened or with silvery streaks.....*Thrips*
(Refer back to "Thrips," p. 6, for key to species)
- ee. Body oval
 - f. Very small, $\frac{1}{40}$ to $\frac{1}{60}$ inch, mites or spiders; body not divided into head, thorax, and abdomen; with 4 pairs of legs.....*Mites or spiders*
(Refer back to "Mites or spiders," p. 5, for key to species)
 - ff. Larger in size, $\frac{1}{16}$ to $\frac{1}{4}$ inch; head, thorax, and abdomen plainly differentiated; occurs on new growth; with 3 pairs of long legs and antennae.....*Aphids or plant lice*
 - g. Blackish to dark brown or greenish..Black citrus aphid
 - gg. Light green to dark olive-green
 - h. Body of adults of a light-green color, similar to new citrus foliage, the immature aphids slightly paler
.....Citrus aphid
 - hh. Body of adults usually dark olive-green or with a slate-blue cast ranging almost to blackish.....
.....Melon or cotton aphid

C. Infesting twigs

- a. Covered with a white, waxy powder or with cottony egg masses
 - b. Fluted masses of white cottony material containing red eggs in association with soft, plump, red-bodied insects with beaks inserted in tissue.....Cottony cushion scale
 - bb. Masses of white cottony material, not regularly fluted, in association with flat, elongate oval, white wax-covered insects.....*Mealybugs*
(Refer back to "Mealybugs," p. 4, for key to species)

- aa. Not covered with white waxy powder and without cottony masses
 - b. Removable hard shell or scale covering, over soft, sac-like, plump, yellow or whitish bodies; shells circular or elongate; legs and antennae lacking; firmly attached to plant by long beak inserted into the tissue
*Armored or diaspine scales*
 (Refer back to "Armored or diaspine scales," p. 5, for key to species)
- bb. Not covered with a hardened detachable scale
 - c. Flattened, oval, gray disks, overlapping and arranged in two parallel rows on smaller twigs.....*Angular-winged katydid, eggs*
 - cc. Hemispherical or gall-like, slightly convex, black, brown or grayish; not arranged in regular overlapping rows.....
*Mature unarmored or lecanine scales*
 - d. Hemispherical or gall-like, black in color; a distinct raised H on back.....*Black scale*
 - dd. Slightly convex, grayish or brownish
 - e. Brownish in color, the infestations usually limited to single trees or single branches; variable in size.....*Soft brown scale*
 - ee. Grayish in color, the infestations usually generally distributed throughout the trees; uniform in size.....*Citricola scale*

D. Infesting trunk

- a. On old trees, beneath loose bark, particularly on shell-bark trees....*Red scale*
- aa. On young trees, small trunks
 - b. Hemispherical or gall-like, or slightly convex, of a rubbery or leathery texture.....*Mature unarmored or lecanine scales*
 (Refer back to "Mature unarmored or lecanine scales," above, for key to species)
 - bb. White cottony masses
 - c. Elongate masses regularly fluted, containing red eggs
*Cottony cushion scale*
 - cc. Irregular-shaped masses of fine waxy threads containing yellow eggs.....*Mealybugs*
 (Refer back to "Mealybugs," page 4, for key to species)

II. General classification by types of damage: insects rarely seen on plants, or type of injury more convenient guide to identification of the insect than the insect itself; identification by type of injury

A. Injury to fruit

- a. Discolored fruits, the rind not eaten away, perforated or coarsely scarred
 - b. Silvery streaks or blotches discoloring the fruit, especially lemons in San Diego County.....*Silver mite*
- bb. Mottled gray on green fruit and abnormal pale yellow on mature fruit
*Red spider*
- aa. Perforations, scars, pits, or abrasions
 - b. Holes perforating the rind or extending into the pulp
 - a. Small holes, no larger than the lead of a pencil, the holes usually where fruits are in contact.....*Orange tortrix or Holcocera*
 - cc. Large holes, $\frac{1}{4}$ inch in diameter.....*Cutworms*

bb. Without holes penetrating into the rind or pulp*c.* Rind not distinctly pitted but marred by scars or abrasions only

d. Scarring uniform, in a circle around stem end, the scarred tissue grayish in color and often depressed; other scarring on distal end and side.....Citrus thrips

dd. Scarring irregular, not confined to the stem end and not always depressed.....Thrips or wind injury

cc. Rind pitted, the impressions deeper than in *c*

d. Deep pits showing portions of the rind having been eaten awayKatydid or grasshopper

dd. Pits not showing feeding marks in rind

e. Irregular, brown pits of various sizes.....Fumigation injury

ee. Circular pits around stem ends of mature Valencias.....Fumigation injury

B. Injury to leaves

a. Leaves with parts of the margin eaten away

b. Parts of the epidermis as well as parts around the entire margin eaten away, giving a ragged appearance.....Diabrotica

bb. Epidermis on the surface of the leaves uninjured, only edges eaten away

c. Injury mostly, if not entirely, confined to leaves on the lower shaded portions of the tree.....Fuller's rose weevil

cc. Injury similar to the foregoing, except that the exposed leaves on the upper parts of the tree are eaten as well as those on the lower shaded parts.....Grasshopper and katydid

aa. Leaves entire without parts of the margin eaten away

b. Leaves at tips of twigs curled.....Aphids

bb. Epidermis with mottling or silvery streaks or abnormally thickened

c. Leaves thickened, distorted, and with silvery areas or streaks..Thrips

cc. Leaves not abnormally thickened but grayish or mottled due to destruction of chlorophyll.....Red spider

ccc. Leaves with yellow raised areas on upper side.....Six-spotted mite

C. Injury to twigs

a. Ragged punctures in a row along smaller twigs, especially in Coachella Valley.....Cicada

D. Injury to trunk

a. Exudations of gum, on large trees often in a spiral thread, rare, not injurious to tree.....Fumigation injury

aa. Exudation of gum on young trees up to two or three years, and portions of bark eaten away, sometimes girdled.....Fire ant

E. Injury to roots

a. Shallow surface tunnels gouged out.....Fuller's rose weevil

RED SPIDERS AND MITES

(Class Arachnida; order Acarina)

With the exception of scale insects and mealybugs, red spiders and mites are the most important pests of citrus trees in California. Fifteen or twenty different species, including predacious forms, may be found on the citrus trees; but only three are of economic importance, and of these one is much more important and more widespread than the other two.

Red spiders and mites occur chiefly in the coastal areas and only occasionally in such interior districts as Riverside and Redlands in sufficient numbers to warrant treatment. They do not occur as pests at all on citrus in the Coachella, Imperial, San Joaquin, and Sacramento valleys.

CITRUS RED SPIDER, *PARATETRANYCHUS CITRI* MCGREGOR

(Family Tetranychidae)

The citrus red spider causes the more characteristic mite injury, as represented first by pale-colored areas over the surface of the leaf and fruit; these areas gradually increase in number until they become numerous enough to produce a general pale gray or silvery effect. When the mites are abundant, the tender twigs are also attacked and many eggs and cast skins may be seen on the fruit, leaves, and twigs.

This species is the most widely distributed of all of the species and occurs most abundantly in the coastal area, but sometimes it does damage in Riverside and San Bernardino counties. It seems to be limited almost entirely as a pest to citrus trees. Attacks on other plants infested with red spider that may be growing in the vicinity will always be found to be due to another species.

Life History.—The egg (fig. 1) of the citrus red spider differs from that of the other species occurring on citrus by the presence of a vertical stalk from the top of which radiate several guy threads. The egg is nearly spherical, slightly flattened vertically, and when first laid is a uniform bright red color. Later the color pigment gathers in particular areas, usually at one side, and finally the eyes and outline of the developing nymph can be distinguished.

The number of eggs produced averages about 30, and usually 2 or 3 are deposited each day. The time required for the eggs to hatch varies from 8 or 10 days in the summer, to 3 weeks or longer in the winter.

The young mite is much like the adult, except that it is smaller in size and has but three pairs of legs, the fourth pair being acquired during the first molt.

Feeding begins immediately after hatching and on the second or third day the first molt occurs; after 2 or 3 days more the second molt takes place, and a similar period elapses before the third and last molt.

The citrus red spider (fig. 1) is not difficult to distinguish from the others found on citrus trees. It is distinctly red, commonly a dark

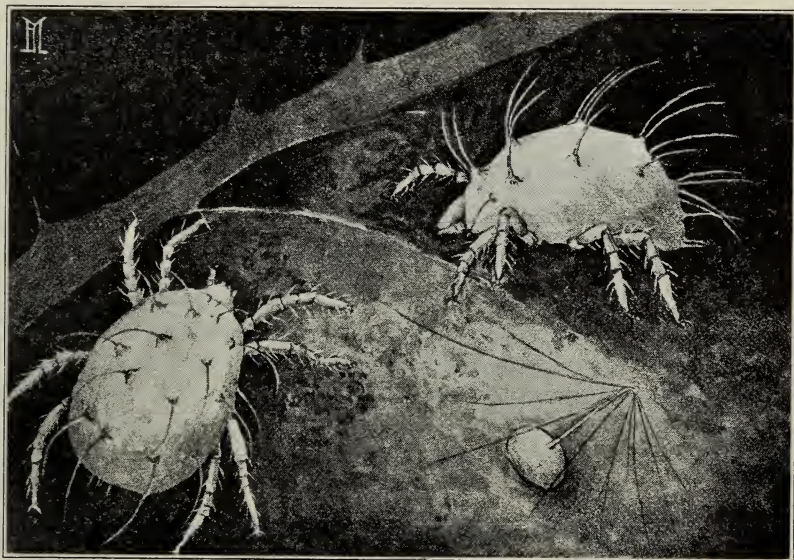


Fig. 1.—Citrus red spider, egg and adults. (From Bul. 234.)

velvety red. The white bristles which occur on the body arise from prominent tubercles; none of the other species on citrus have these tubercles.

This mite ordinarily appears in greatest numbers during the early spring or late fall. It is less abundant during the high temperatures in the summer, and in most of the area is not abundant in the winter, although this species may be found in large numbers during the winter in the San Diego section.

SIX-SPOTTED MITE, *TETRANYCHUS SEXMACULATUS* (RILEY)

(Family Tetranychidae)

The six-spotted mite is more strictly limited to coastal areas than is the citrus red spider. Its work is very characteristic and is easily distinguished from that of the other species. Feeding is confined to par-

ticular areas on the leaf. The mites occur on the underside of the leaf, usually along the midrib or larger veins. There is a distinct depression formed where a colony is located. This depression is of a pale yellowish color and is covered by a web that protects the spiders beneath and also serves as a support for the eggs, which can be seen scattered about entangled in the silk. On the upper surface of the leaf this same area is represented by a raised portion or swelling which is distinctly yellow or yellowish-white, and has a smooth shiny surface. In case of severe injury, these areas may make up the greater portion of the leaf and such a leaf may become more or less distorted and misshapen.

Life History.—The egg is white or yellowish-white and is spherical in shape. The eggs are found only in areas where the mites feed. From 25 to 40 eggs are deposited over a period of 10 to 20 days. Five to 8 days are required for hatching in June, and this period is extended at lower temperatures.

The development of this species is much the same as that of the citrus red spider and need not be separately discussed.

The adult of the six-spotted mite is smaller than that of the citrus red spider and is never red. The general color is light pink or greenish-yellow. In some individuals a dark pigment is coalesced into six areas or spots, hence the name *sexmaculatus*, or six-spotted mite. The hairs are not so long as in the citrus red spider, nor do they arise from tubercles.

SILVER OR RUST MITE. *PHYLLOCOPTES OLEIVORUS* (ASHM.)

(Family Eriophyidae)

The silver mite is so called because of the silvery effect which its feeding produces on lemons. It is called "rust mite" in Florida because of the brown or russet effect it produces on oranges. This species belongs to a different group of mites than the two already discussed. The family Eriophyidae includes four-legged mites of a vermiform or worm-like shape, and so small as to be scarcely visible without magnification.

When feeding begins, the injury is much the same as that caused by the citrus red spider, but the ultimate effect is easily distinguished from the work of that species. The silver mite often occurs in such large numbers that lemons become distinctly white or silvery in color, with a network of cracks; the injury is more pronounced than in the severest attack of the citrus red spider, and more restricted to the fruit. The silver mite is restricted to a limited area in San Diego County.

Life History.—The egg of the silver mite is white or transparent, circular in shape, and very small. Four or 5 days are required for hatching during the summer months, and as long as 2 weeks or more in the winter.

The young is elongated and more worm-like than any of the other mites found on citrus trees. The cast skins, which may be seen on the foliage or fruit after the mites themselves have disappeared, are very minute and of a cornucopia-like shape.



Fig. 2.—Silver mite or rust mite. (From Bul. 234.)

The adult (fig. 2) is light yellow in color and is wedge-shaped. It is broadest in front and tapers uniformly to the posterior end, where there are two small lobes which are used for clinging and crawling. It has four short legs by means of which it moves about. It is only $1/200$ inch in length.

PARASITES AND PREDATORS

There is a wide variety of parasites and predators of spiders and mites, including representatives of five orders. In some sections, particularly where control measures for scale insects are not so frequently applied, they aid in checking the spiders; but under favorable weather conditions spiders and mites increase so rapidly that their insect enemies are unable to prevent them from doing damage.

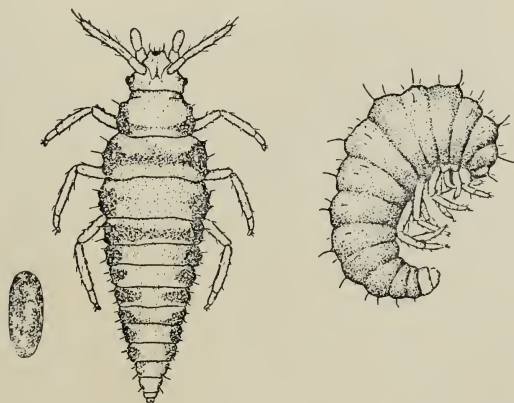


Fig. 3.—*Conwentzia hageni* Banks, eggs, larva, and pupa. This insect feeds on red spider. (From Bul. 234.)

Conwentzia Hageni.—*Conwentzia hageni* Banks is a member of the family Coniopterygidae of the order of Neuroptera.

The egg (fig. 3) is pinkish-yellow and is oval in shape. The surface is marked with hexagonal reticulations. The eggs are deposited singly,

usually on the under surface of the leaf, and they hatch in from 6 to 8 days.

The body of the larva is broad at the anterior end, becoming still wider at the thorax, and tapering gradually toward the posterior end. The color and markings vary considerably, the usual colorings being white, red, and black. The mouth parts consist of a cone-shaped beak enclosing the needle-like mandible and maxillae, the latter being serrate at the tip.

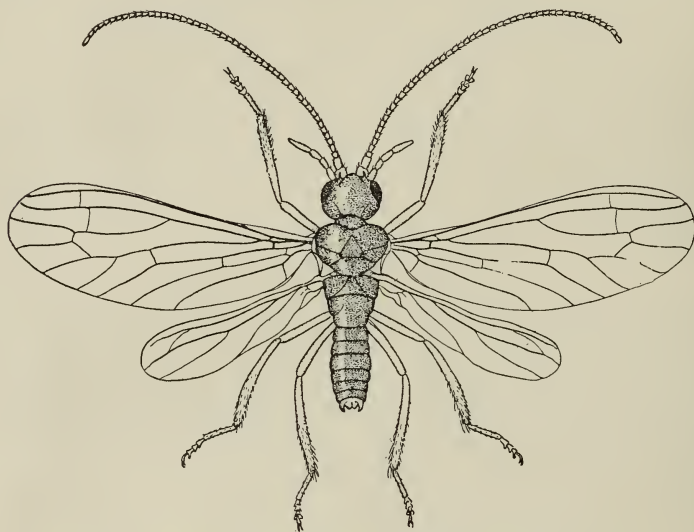


Fig. 4.—*Conwentzia hageni* Banks, adult. (From Bul. 234.)

The larva undergoes 3 molts. The first molt occurs 4 days, the second 10 days, and the third 14 or 15 days, after hatching. Six days later it begins to spin its cocoon, so that the total larval period is from 18 to 22 days.

The larva feeds on all stages of the spider, including egg, young, and adult. Records on the feeding of a larva showed that during its development as many as 250 spiders had been consumed.

Pupation occurs usually on the underside of the leaf and along the midrib, or in other places where there is some protection. The cocoon consists of a double layer of silk: an inner compact layer and an outer, flat, loosely woven web.

The adult (fig. 4) is a very frail insect about $\frac{1}{5}$ inch long, and is grayish white. The wings are covered with a gray powder, hence members of this group are called "dusty wings." The second pair of wings is very small compared with the fore pair. The antennae are long and threadlike.

Brown and Green Lacewings.—The brown lacewing, *Hemerobius pacificus* Banks, belongs to the family Hemerobiidae, and the green lacewing, *Chrysopa californica* Coq., to the family Chrysopidae. Both of these insects, like the *Conwentzia hageni* just discussed, are members of the order Neuroptera.



Fig. 5.—Brown lacewing, *Hemerobius pacificus* Banks, larva and adult.
This insect feeds on red spider. (From Bul. 234.)

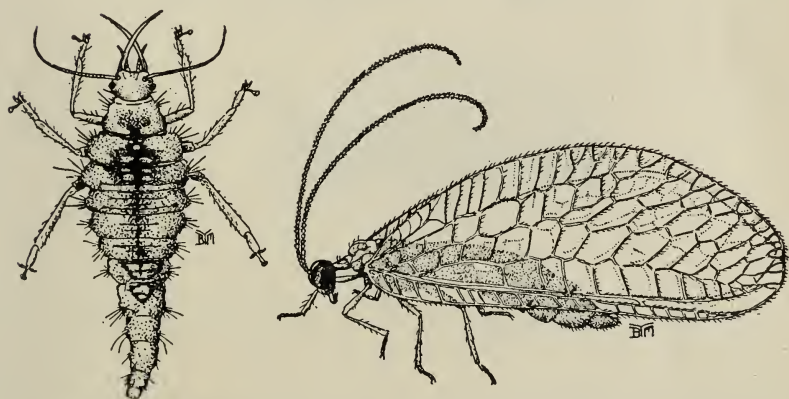


Fig. 6.—Green lacewing, *Chrysopa californica* Coq., larva and adult.
This insect feeds on red spider. (From Bul. 234.)

The eggs of the brown lacewing are laid singly on the under surface of the leaf. They are white, marked with spiral reticulations, and at one end is the knob-like micropyle. The eggs of the green lacewing are the familiar long-stalked eggs that usually occur in groups.

The larva of the brown lacewing (fig. 5) feeds on red spider. A total of 897 spiders have been consumed by a single larva.

The larva of the green lacewing (fig. 6) also feeds on red spiders. It may be distinguished from that of the brown lacewing by the rings or segments, which are more widely placed on the basal half of the antennae, as compared with those more distal. The ice-hook-like mandibles of the green lacewing are also longer and more slender than those of the brown lacewing.

From figure 6, the adult of the green lacewing will be readily distinguished. It is green and is $\frac{3}{5}$ inch long, while the brown lacewing adult (fig. 5) is smaller ($\frac{2}{5}$ inch long), somewhat differently shaped, and brown.

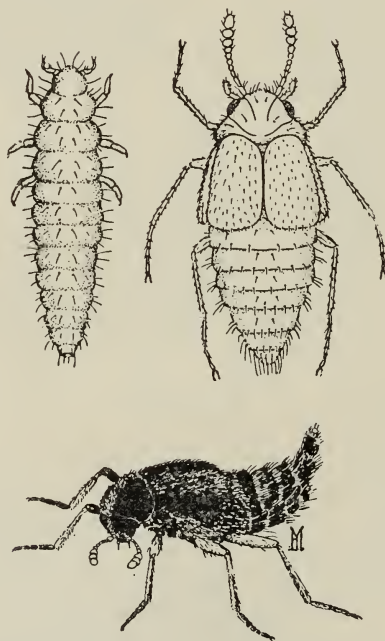


Fig. 7.—*Oligota oviformis* Casey, larva and adult. The characteristic position of the adult is shown below. This insect feeds on red spider. (From Bul. 234.)

Oligota Oviformis.—*Oligota oviformis* Casey is a member of the family Staphylinidae of the order Coleoptera.

The egg is light orange, oval in shape, and has a slightly reticulate surface. The eggs are laid singly on the under surface of the leaf and hatch in 7 to 9 days.

The length of the full-grown larva (fig. 7) is about $\frac{1}{10}$ of an inch. It is narrower at the anterior end, and is yellow. About 20 spiders may be consumed daily, or a total of 200 or 300 spiders during the course of larval development.

The adult (fig. 7) is a small, black, peculiarly shaped beetle, with short wing covers, and with the tip of the abdomen strongly curved upward. The head is bent under and vertical, and is not visible from above. The adults were found to consume about 10 spiders a day for a maximum adult life of 32 days, making a total consumption of 320 spiders by one beetle.

Stethorus Picipes.—*Stethorus picipes* Casey is a member of the family Coccinellidae of the order of Coleoptera. It is the commonest coccinellid that feeds on red spider.

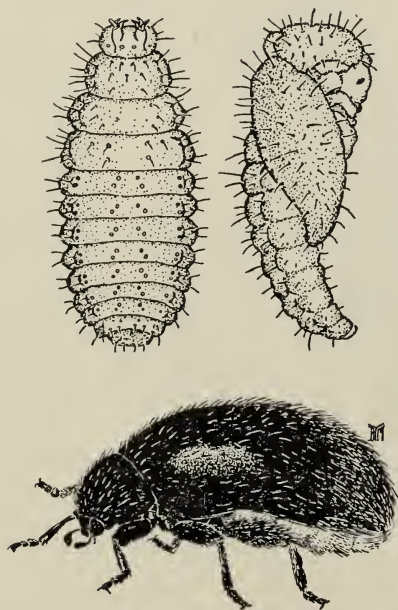


Fig. 8.—*Stethorus picipes* Casey, larva, pupa, and adult. This insect feeds on red spider. (From Bul. 234.)

The egg is oval in shape and is pinkish-yellow when first deposited; as hatching time approaches it turns black or dark gray, and the surface is marked with hexagonal reticulations. The eggs are deposited singly, usually on the under surface of the leaf.

The larva is dark gray to black, and is about $\frac{1}{25}$ inch long. The body is clothed with numerous hairs arising from small tubercles (fig. 8). The length of its life is about 30 days. Feeding records of the larva indicate that an average of 6 or 7 spiders are consumed daily.

The adult (fig. 8) is a polished black beetle clothed with fine hairs, and is about $\frac{1}{25}$ inch long.

Scolothrips Sexmaculatus.—*Scolothrips sexmaculatus* (Pergande) is a member of the family Thripidae of the order Thysanoptera. It is a predacious thrips (fig. 9) and is commonly found feeding on red spiders. For the most part, the eggs and young spiders are attacked,

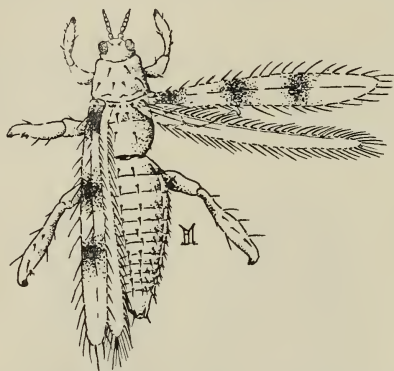


Fig. 9.—*Scolothrips sexmaculatus* (Perg.). This insect feeds on red spider. (From Bul. 234.)



Fig. 10.—*Arthrocnodax occidentalis* (Felt), adult and larva. This insect feeds on red spider. (From Bul. 234.)

though fully matured spiders are taken occasionally. Both the larvae and the adults of the thrips have been observed feeding on the spiders.

Arthrocnodax Occidentalis.—*Arthrocnodax occidentalis* Felt (fig. 10) is a member of the family Cecidomyiidae of the order Diptera. It

occurs in greatest abundance on the six-spotted mite, where the definite colonies, together with their protective covering of web, seem to offer the best conditions for the larva. Not having great powers of locomotion, it finds the spiders massed in a colony an advantage in the capture of food.

Triphleps Tricolor.—*Triphleps tricolor* White is a member of the family Anthocoridae of the order Hemiptera. It is a carnivorous bug, $\frac{1}{12}$ inch long, and black (fig. 11). Both the nymphs and adults feed on spiders as well as on many insects.

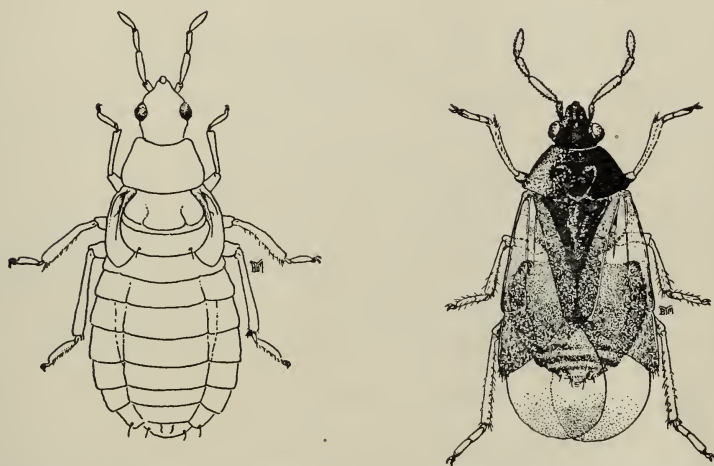


Fig. 11.—*Triphleps tricolor* (White), nymph and adult. This insect feeds on red spider. (From Bul. 234.)

CONTROL OF SPIDERS AND MITES

Formerly sulfur, either as a spray or dust, was depended upon for the control of spiders and mites on citrus trees. Sulfur dust is effective, provided proper weather conditions prevail. Lime-sulfur spray was less dependent upon the weather and controlled the spiders satisfactorily, but it was necessary, as with dry sulfur, to repeat the application sometimes within a short time. Since oil sprays have come to be so generally used for control of those scale insects that have become resistant to fumigation, oil sprays are now very largely depended upon for the control of spiders in California because of their prolonged effect.

A heavy oil (grade 5) will insure freedom from spiders for an entire year. Such a heavy oil, however, is no longer used except on lemons. (See "Oil Sprays," page 79.)

A medium oil (grades 3 and 4), when applied during the early fall months, usually results in satisfactory control of the spider for a year.

In some cases, particularly where this spray is applied during July and August, a reinfestation may appear the following spring.

For temporary control of the spider, a light oil (grades 1 and 2) is satisfactory, though the protection does not extend over such a long period as that of either a medium or heavy oil.

Where oil spray is applied, it is generally used also for scale insects. Therefore the combination of the two pests should be taken into consideration in a control program. (See "Treatment for Combination of Pests," page 71.)

KATYDIDS AND GRASSHOPPERS

(Class Insecta, order Orthoptera)

Katydids and grasshoppers are not very important citrus pests in California. However, in some cases where there is a large area of uncultivated ground surrounding citrus plantings, there may be damage by grasshoppers; and katydids sometimes cause injury, particularly in the San Joaquin citrus area. Two species of katydids are concerned: one, the fork-tailed katydid, *Scudderia furcata* Brun.; and the other, the angular-winged katydid, *Microcentrum rhombifolium* Sauss.

FORK-TAILED KATYDID

The fork-tailed katydid is the commoner and usually the more injurious species. Young katydids appear on the trees about the time the petals fall. Sometimes the blossom buds will be attacked. While they feed on both the leaves and fruit, the chief injury is done to the fruit. This injury consists of a deep hole gouged in the young fruit, which results in a permanent scar.

The eggs of this species are inserted into the edges of the older and rather tough leaves, between the upper and lower surface. The edge of the leaf where the egg is inserted is generally slightly chewed away and the sharp tip of the egg may be seen protruding from the cut. There is also a slight oval swelling on the edge of the leaf, which indicates the presence of the egg.

There is one generation of the fork-tailed katydid, the nymphs appearing in May and the first adults early in June.

ANGULAR-WINGED KATYDID

The angular-winged katydid may be distinguished from the other species by its size (1½ to 2 inches to tip of wings) and broad wings, and by the hunchback appearance of the nymph and the adult.

The eggs are laid alternately in double rows along the sides of twigs from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. The larger egg groups are composed of 24 or more eggs, each about $\frac{1}{5}$ inch long. They are dark gray in color and oval in shape. Specimens of these eggs are sent in every year for identification in the belief that they are a species of scale insect.

CONTROL

If these insects become numerous enough, an application of barium fluosilicate or cryolite would be warranted; but, as a rule, it is very rarely that anything is done for their control. Barium fluosilicate was applied on some trees a few years ago, but the katydids did not appear that year in large enough numbers to make any reliable determination of the results.

TERMITES

(Class Insecta, order Isoptera)

Termites, often mistakenly called "white ants," are social insects living always enclosed in galleries in wood or the ground, save at the time of swarming of the colonizing alates, or winged forms. The colonies consist of individuals in various nymphal instars and of adults of several castes, soldiers, workers, and reproductives. Their food is wood or cellulose in some form. Certain termites live in dry wood, others in damp or decaying wood, and others in the earth, extending their activities to wood in or on the ground or building covered runways to reach wood above the ground.

As a rule termites do not attack the living parts or the sound wood of living trees; they are, therefore, relatively unimportant as citrus pests. However, there are records of occasional attacks by termites on dead citrus wood aboveground, on rootstalks below ground, and on the bark of the trunk aboveground. The species so far reported as responsible for such damage are the desert subterranean termite (*Heterotermes aureus* Snyder), the western subterranean termite (*Reticulitermes hesperus* Banks), the desert termite (*Amitermes acutus* Light), the desert damp-wood termite (*Kaloterms simplicicornis* Banks), the common damp-wood termite (*Termopsis angusticollis* Hagen), and the common dry-wood termite (*Kaloterms minor* Hagen).

The dry-wood termite commonly attacks dead citrus wood aboveground and the common damp-wood termite rarely so. Neither is known to be important. They are not found in the Coachella or Imperial valleys, but are common in other citrus-growing areas.

The desert subterranean and the desert termites have been reported as destroying the bark under cover of earthen runways. Attacks by the

former are rare, and are confined (in California) chiefly to the Coachella and Imperial valleys; those that have been reported have been associated with the bud scar or with the presence of cardboard wrappings. Attacks by the latter have been reported from Redlands and Corona.

The western subterranean termite occasionally attacks dead or injured roots and probably works into the heartwood of weak trees, but such attacks are exceedingly rare. The species is common in most citrus-growing areas except the Coachella and Imperial valleys.

The desert damp-wood termite attacks the rootstalk and crown roots below ground, severing the rootstalk of young trees. This species has caused the death of a small percentage of grapefruit and tangerines planted in recently reclaimed desert land that had had considerable woody growth before it was cleared.

THRIPS

(Class Insecta, order Thysanoptera)

CITRUS THRIPS, SCIRTOTHRIPS CITRI (MOULT.)

The citrus thrips is one of the important insects in connection with citrus growing in California, particularly in the San Joaquin Valley. It is an insect that is limited in its distribution to the warm, dry sections of the citrus area. Aside from the San Joaquin Valley, it occurs in southern California, most commonly in the Riverside-Redlands area and in the vicinity of Piru in Ventura County.

Injury.—The citrus thrips obtains its food by rasping and puncturing the tissues, causing a very characteristic scarring of the fruit due to the dead dry cells. The most characteristic form of injury is a well-marked ring around the stem end, although more or less irregular and indefinite areas occur on other parts of the fruit (fig. 12). Sometimes the attack is so severe as to cause the fruit to be distorted. In addition to attacking the fruit, it also attacks the young growth, causing the leaves to become deformed, leathery, and more or less curled. The attack on the young growth is often so severe as to be an important check on the growth of the tree. In the fall it feeds on the buds, destroying them or causing a rosette-like effect.

Life History.—The egg is deposited within the tissues of the leaf, or the smaller, more succulent stems. The winter is spent in the egg stage, the first larva appearing some time in February or March, according to the season.

The larva becomes active immediately after emergence and feeds continuously during the course of its development. It undergoes four

molts, comprising two in the larval stage and two in the pupal stage. The first molt takes place on the leaves and fruit, the remainder in some hiding place, often in débris on the ground.

Other species of thrips, such as *Frankliniella occidentalis* (Perg.), occur in the blossoms of citrus and other plants and are sometimes mis-



Fig. 12.—Work of citrus thrips on oranges. (From Bul. 214.)

taken for the citrus thrips. The citrus thrips is smaller than the smallest flower thrips and is more orange or sulfur-yellow in color. The body is widest at the third segment of the abdomen and tapers abruptly to the tip, while the flower thrips is more cigar-shaped and the body tapers gradually. The citrus thrips is very active and is rarely found in the blossoms, while the flower thrips is slow-moving, and the adults feed chiefly in the blossoms. The larvae of the flower thrips may feed on the green parts of the plant.

Seasonal History.—The life cycle of the citrus thrips is completed in the summer in as short a time as 15 days, and in the spring and fall in about 30 days. There are several generations in a year and they are found on the trees up to November and December, when they gradually disappear.

Predators.—The most important insect enemy of the citrus thrips is the larva of the common green lacewing fly, *Chrysopa californica*. For description, see page 15. Another species of thrips, *Scolothrips sexmaculatus*, sometimes feeds on citrus thrips; *S. sexmaculatus* is described on page 18.

GREENHOUSE THRIPS, HELIOTHRIPS HAEMORRHODALIS BOUCHE

The greenhouse thrips has done severe injury to both fruit and leaves, on a few trees in Santa Barbara County. It also occurs in warm areas, such as the San Joaquin Valley. This species has a long list of host plants and occurs more or less infrequently on citrus.

BEAN THRIPS, HERCOTHRIPS FASCIATUS (PERGANDE)

The bean thrips occurs incidentally on navel oranges, where it seeks protection in the navel, and its presence on such fruit after harvesting has recently been a matter of importance in exporting to Hawaii.

CONTROL OF THRIPS

Commercial lime-sulfur, used at a strength of 1½ and 2 per cent, has been the chief reliance for thrips control from the beginning and is still a satisfactory material. During the past few years, however, E. A. McGregor, who has been working on the thrips problem for the United States Department of Agriculture, has found that sulfur applied dry is effective. McGregor's recommendation for thrips in Tulare County is:

1. Apply 1 pound of sulfur for the average-sized tree when the first warm weather occurs in the spring, which is usually between March 20 and April 10.
2. Apply ¾ pound for the average-sized tree when the trees are in full bloom. This will usually be between April 20 and May 1.
3. Apply ½ pound of sulfur for the average-sized tree during the last week of May or the first week of June, this to be applied largely on the north side of the tree, to avoid injury on account of warm weather.

Where lime-sulfur spray is used, it should be applied when the petals have fallen from the south side of the tree and while the north side of the tree is in full bloom. A second spray should be applied two or three weeks later.

Some growers in Tulare County prefer to apply a 4 per cent or 5 per cent lime-sulfur spray in the winter or early spring, January, February, and early March. Sometimes this is followed by a spray or two applications of dust, these later applications to be made when the petals fall, and three weeks later.

APHIDS

(Class Insecta, order Homoptera, family Aphididae)

MELON OR COTTON APHID, CITRUS APHID, AND BLACK CITRUS APHID

There are three important species of aphids that attack citrus trees in California, namely, melon or cotton aphid (*Aphis gossypii* Glover), citrus aphid (*Aphis spiraecola* Patch), and black citrus aphid (*Toxoptera aurantii* [Koch]). The two former species are very similar and difficult to distinguish, and often occur more or less associated.

Watson gives the following color differences:

The citrus aphid is of a uniform light green color, like that of the tender citrus leaf; the very young ones a trifle paler. When the wing pads appear the thorax turns first a light pink color and finally, as the wings develop, a dark brown, almost black. The abdomen usually remains green. The melon aphid is very variable but the younger stages are usually a light yellowish-green, much lighter than the corresponding stages of the citrus aphid. The older stages are usually much darker, a dark olive-green, some of them having a slate-blue cast, varying almost to black.

The black citrus aphid is dull or shiny black, or brownish, and with the two black projections (stigma) near the tip of the body.

The aphids attacking citrus in California often do damage in the coastal areas, but they are of little importance in such interior sections as Riverside or Redlands, or in the San Joaquin, Sacramento, Coachella, and Imperial valleys. They appear in the early spring and disappear with the warmer weather of summer.

PARASITES AND PREDATORS

There are a large number of both parasites and predators, the chief groups of which are braconids, syrphid flies, and ladybird beetles, that attack citrus aphids. These enemies are often important in preventing the damage that might otherwise be done. A parasitic fungus is also not uncommon, and is an important check on the aphids.

CONTROL OF APHIDS

Since a large portion of the growth on young trees may be susceptible to attack by aphids, it is important, particularly in the coastal areas, to prevent damage to the young growth, because this damage severely checks the trees. It is also important, of course, to protect such new growth as may be present on older trees.

The treatment is either a spray or dust, the essential constituent of which is nicotine. In the case of a spray, the nicotine is usually used with a spreader, such as calcium caseinate; but, because red spiders may appear coincidentally with the aphids, a spray for both the spiders and aphids is often desirable and practicable. For this purpose $1\frac{1}{2}$ to 2 per cent commercial lime-sulfur solution is used, with the addition of $1\frac{3}{4}$ pints of nicotine sulfate to 200 gallons of diluted spray. A nicotine dust of at least 6 per cent nicotine sulfate (40 per cent) is also applicable, and the dust may be forced into the curled portions of the leaves probably better than a spray. Spray or dust for aphids should be applied only during calm weather.

The trouble with most of the control work on aphids is that the injury has been largely done and the aphids are on the decline before the treatment is applied. A wrong impression is likely to be gained, therefore, of the effectiveness of the insecticide. Also, when the control is delayed, the leaves are so badly curled that the proper application of an insecticide is difficult. If, from past experience, a grower may expect aphids to appear in large numbers and do damage, he should be prepared for treatment upon their first appearance in the spring.

SCALE INSECTS⁶

(Class Insecta, order Homoptera, family Coccidae)

RED SCALE, *AONIDIELLA AURANTII* (MASK.)

The red scale is one of the most important of the citrus insects, and where it has developed a tolerance to hydrocyanic acid gas it is the most difficult of all of the scale insects to control at the present time. It was introduced into California in the early 70's from Australia, and it now occurs very generally over the coastal and interior citrus areas of southern California. In central and northern California it is largely replaced by the yellow scale.

Injury.—No citrus scale in California so quickly and permanently injures the tree as the red scale. It infests all parts, including the

⁶ Control of scale insects is discussed on pages 65 to 71.

leaves, fruit, branches, and trunk. Branches of considerable size are frequently severely injured in a single season's infestation. There may be heavy defoliation. Badly infested fruits are unmarketable. All of this injury is done by the feeding alone, since no honeydew is excreted.

Food Plants.—A long list of host plants is recorded as being attacked by this scale. Of the varieties of citrus, it is probably most abundant on the lemon; at least its control on the lemon tree presents the greatest problem at the present time. In addition to all varieties of citrus, other important host plants often found in the vicinity of citrus

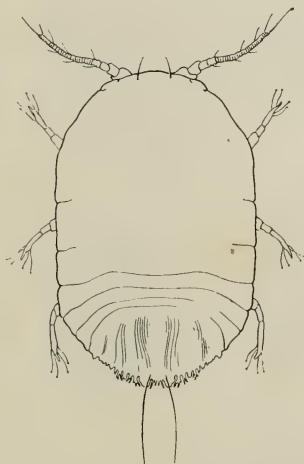


Fig. 13.—Motile young or “crawler” of red scale. (From Bul. 222.)

are: the rose, castor bean, nightshade, laurel-sumac, and willow, camphor, eucalyptus, carob, mulberry, avocado, and fig trees. There are also a few infestations in the English walnut. Rose hedges bordering citrus orchards are often a source of infestation.

Life History.—The red scale does not deposit eggs, but gives birth to young (fig. 13). As many as 150, or more, young may be produced over a period of 2 months by a single female. Upon emerging from beneath the female, the yellow, oval-shaped young crawl about actively for a few hours to a day or two, when they settle and, in the case of the females, remain for the rest of their existence.

After settling, the young scale soon begins the secretion of a white, cottony covering (fig. 14, A) and in this stage they are called “white caps.” The first molt occurs in from 7 to 20 days; and the second in from 12 to 20 days more. During the first molt the legs and antennae are lost and the oval crawler becomes circular. The upper part of the

cast skin is incorporated in the white cottony covering and this becomes depressed and compact, and of a reddish color. The upper portion of the second cast skin likewise becomes incorporated in the scale covering, which is larger but otherwise similar to the first. The two cast skins may be distinguished by the circles seen in the scale covering (fig. 14, *A*).

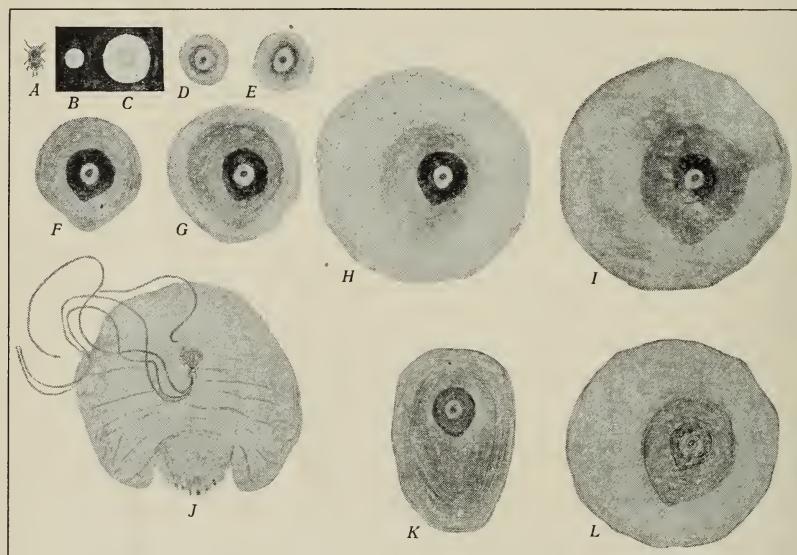


Fig. 14.—The development of the red scale as it appears on the plant. *A* to *J*, stages of the female scale: *A*, motile young or "crawler"; *B*, white cap; *C*, nipple stage; *D*, first molt; *E*, secretion of gray wax margin after first molt; *F*, second molt; *G*, secretion of gray wax margin after second molt; *H*, completion of extension of scale covering by enlargement of gray wax margin. This stage may be called the gray adult. *I*, the adult or young-producing stage.

The first cast skin is incorporated in the scale covering, as shown by the darker inner circles in *F*, *G*, *H*, and *I*. The second cast skin is represented by the outer margin in *F*, and the same cast skin may be distinguished in *G*, *H*, and *I*.

In stages *D*, *F*, and *I*, the covering may not be lifted without taking with it the insect itself. In the other stages represented, the covering may be lifted free from the insect.

J, The adult female as it occurs under the scale covering *I*. The threads represent the mouth parts, which are inserted into the plant. Their length may be twice the diameter of the adult insect.

K, The scale covering of the male. The same first cast skin may be noted. The cast skins from the other three molts of the male are not incorporated in the scale covering. The winged male emerges from beneath the narrower (lower) end of this covering, at a time when the same-aged female is in stage *H*, or between stages *G* and *H*.

The photograph was taken from a colored chart and the different shades are not correctly reproduced. On the original chart, *L* represented the yellow scale. The yellow scale is similar in size to the red scale, but it is of a lighter color.

All of the figures are of the same relative size, with an enlargement of 20 diameters.

During all of this time the scale revolves, with its beak remaining in the tissues as a pivot (fig. 15). Thus, by means of the so-called "pygidium" with its lobes and plates, the wax is molded and compacted in circular form and extended beyond the insect itself to provide for future growth. Ten to 20 days after the second molt of the female, the adult male emerges and fertilization occurs.

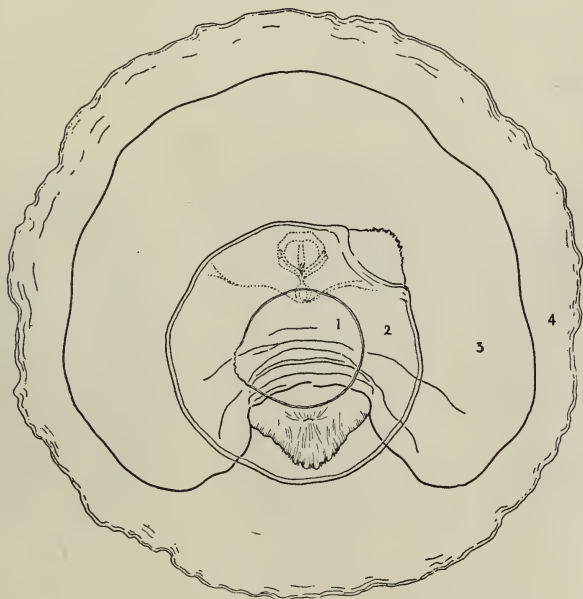


Fig. 15.—Mature red scale, showing cast skins and scale covering. Note from the different positions of the pygidial characters that the insect has rotated in the course of its development. (1) First cast skin; (2) second cast skin; (3) the insect; (4) the scale covering. (From Bul. 222.)

There are thus three stages in the development of the female red scale: the first stage extending from emergence to the first molt; the second stage from the first to the second molt; and the third stage from the second molt to and including maturity. During the molts and the young-producing period, the insect and its covering are intimately associated, so that the covering cannot be lifted without also lifting the insect. Between the molts, and up to the time of fertilization, the covering can readily be lifted, leaving the insect free. The female red scale grows considerably after the second or last molt. Provision is made for this growth by an expansion of the wax covering, which is indicated by a wide gray margin. The third stage may thus be further divided into two stages: one, when the insect is free from its covering and has a wide margin of gray wax extending beyond the insect; and the other,

from the time of fertilization and during the young-producing period, when the covering and the scale are inseparable. Scales in the third stage are the ones that are most likely to be seen alive a week or two after fumigation. At the time of fumigation many of these insects are in the second molt, and it is during this particular period that the red scale is most resistant to fumigation.

The male insect follows a very different development (fig. 16) from that of the female. After the first molt the male scale insect becomes elongated and has two pairs of conspicuous purple eyes, although the pygidial characters are much like those of the same stage in the female.



Fig. 16.—Stages of the male of the red scale: (1) second stage; (2) prepupa; (3) pupa. (From Bul. 222.)

During the second molt the prepupa is formed; during the third molt the true pupa is formed; and finally, in the fourth molt the pupa transforms into the winged adult male (fig. 17), which shortly thereafter makes its appearance by emerging backward from beneath the scale covering.

Seasonal History.—Studies carried on in a shaded greenhouse during July, 1931 (an unusually warm month), showed that some males emerged 28 days after settling, and the total period from the settling of female young to the appearance of young from the same scales may be as short as 42 days. The range in temperature was from an average minimum of 71.2° F to an average maximum of 90.8° F. These scales were grown on the fruit of both the orange and the lemon. Growth was somewhat more rapid on the fruit than on the leaves. The time of development given is the shortest recorded. During cooler weather the

time has been extended to 150 days, or longer, and 75 to 90 days represents a general average. Three to five generations occur in a year, according to the locality and the season.

Dispersion.—The red scale may be distributed over long distances on nursery stock or fruit. A spread over the same general community is effected by the wind, by birds and insects, and also by man in his

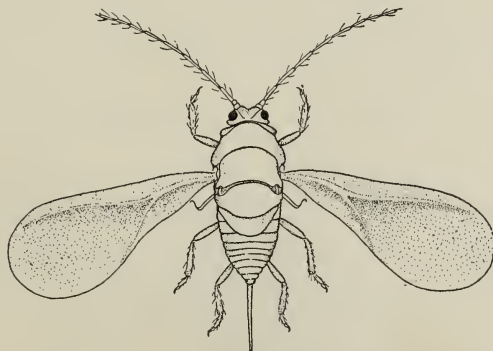


Fig. 17.—Male of the red scale. (From Bul. 222.)



Fig. 18.—*Aphytis chrysomphali* (Mercet), a parasite of the red and yellow scales.

usual cultural operations. This spread occurs only while the scale is in the “crawler” stage, but this stage may occur at all seasons except during the colder weather of winter. Young red scales have been captured after having been blown by the wind for a distance of 400 feet, and no doubt the wind may carry them a much greater distance.

Parasites and Predators.—The commonest of the parasites occurring on the red scale in California is *Aphytis chrysomphali* (Mercet). The adult of this species (fig. 18), which is of a general yellow color with

black eyes, may be seen running about in infestations of the red scale. The egg is deposited beneath the scale covering but outside the body of the insect proper. Upon hatching, the larva attaches itself to the scale, from which it draws its nourishment. It is not, therefore, strictly an internal parasite, because no stage is wholly within the body of the scale.

Lindorus lophanthæ (Blaisd.), *Orcus chalybeus* (Bdv.), *Chilocorus bivulnerus* Muls., and *Scymnus marginicollis* Mann. are the commonest coccinellids attacking the red scale in California.



Fig. 19.—*Aspidiotiphagus citrinus* (Craw), a parasite of red, yellow, and purple scales.

YELLOW SCALE, AONIDIELLA CITRINA (COQ.)

The yellow scale is similar to the red in its microscopic characters, and because of this it has been considered as a variety of the red. Recently, Nel⁷ has considered it as a distinct species. In general appearance and habits, however, the yellow scale is easily separated from the red. The yellow scale covering is distinctly more yellow than that of the red and it also is smoother and lies flatter on the leaf. The yellow is only found sparingly on the twigs, being largely limited to the leaves and fruit, while the red attacks the twigs as readily as it does the leaves and fruit.

The yellow scale is widely scattered over the coastal and interior citrus areas, but is most abundant in such interior districts as Redlands in southern California, and in the citrus areas of the San Joaquin and Sacramento valleys.

⁷ Nel, R. G., Unpublished manuscript.

This scale may cause heavy leaf-drop, and also mars the fruit, but it is not so injurious to the tree as the red scale because the twigs and branches are not severely attacked.

Since the life history of the two scales is essentially the same, the reader is referred to the discussion under "Red Scale."

Parasites and Predators.—*Aspidiotiphagus citrinus* (Craw) (fig. 19), while it attacks both the red and yellow scales, has been seen most abundantly and commonly on the yellow scale, particularly in the northern part of the state. The egg is deposited within the body of the



Fig. 20.—*Comperiella bifasciata* How., a parasite of the so-called red scale of China; it fails to develop on the red scale in California. It has recently been found to develop readily on the yellow scale.

scale and the larva develops there, so that it is strictly an internal parasite. The adult is yellowish black.

Aphytis chrysomphali (Mercet), the same species that attacks the red scale, also attacks the yellow, and the same predators also attack both scales.

Recently it has been found that *Comperiella bifasciata* How., a parasite introduced from China, breeds readily on the yellow scale, and colonies (fig. 20) of this parasite have been liberated in different parts of the state where the yellow scale is important. It is supposed to attack the red scale in China, but it failed to develop on the red scale in California although it readily attacked the Florida red. The supposition, therefore, is that the so-called "red scale" in China is the yellow scale.

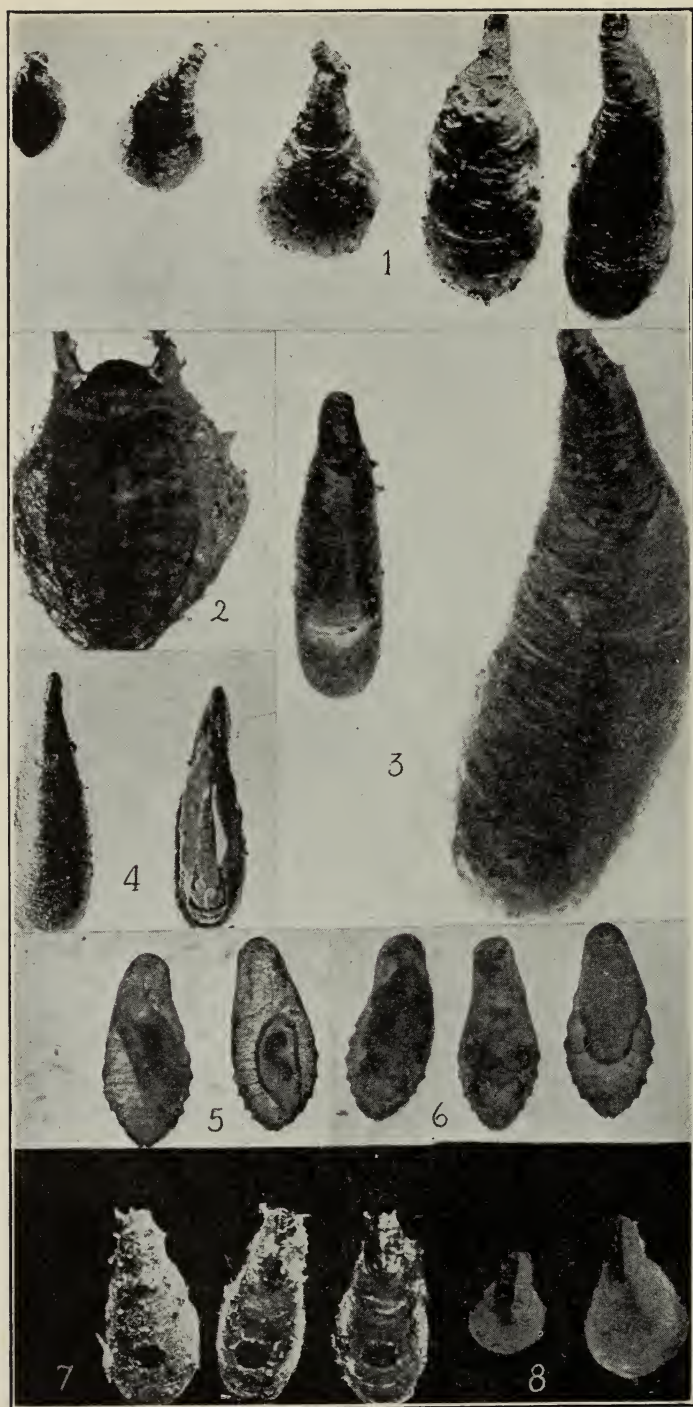


Fig. 21 (See caption on opposite page).

**DICTYOSPERMUM SCALE, CHRYSOMPHALUS DICTYOSPERMI
(MORG.)**

The dictyospermum scale, or Spanish red scale, is the species of scale that is a serious insect pest of citrus trees in the western Mediterranean basin. Thus far it has been restricted largely to *Kentia* palms and avocados in California; but recently an infestation on a few lemon trees was found at Saticoy, and has been eradicated.

In general appearance the dictyospermum scale is more nearly like the yellow than like the red scale. Microscopically it is readily distinguished from the yellow or from the red scale by the presence of circumgenital pores, of which there are from 2 to 4 in each of the four groups.

PURPLE SCALE, LEPIDOSAPHES BECKII (NEWM.)

The purple scale was introduced into California from Florida in 1888 or 1889. It occurs in San Diego, Orange, Los Angeles, Ventura, and Santa Barbara counties. It does not occur in Riverside and San Bernardino counties, although practically contiguous plantings of citrus occur from the coast into these counties. The purple scale is a coastal species and does not thrive well or at all in interior sections.

Food Plants.—The food plants of the purple scale are more strictly limited to the different varieties of citrus than any of the other citrus scales in California, with the possible exception of the citricola scale. There are no host plants of any importance closely associated with citrus, like the pepper and olive with the black scale, or the rose and willow with the red scale.

Life History.—The oval, white eggs of the purple scale are readily seen upon turning over the scale. The number of eggs vary from 40 to 80 and are deposited over a period of 4 weeks, those at the broad end of the scales being the oldest. The space beneath the covering at first occupied by the adult female is gradually filled with eggs as the parent contracts in size toward the anterior end during the course of egg production.

The white, oval larva crawls about for a few hours or a day or two, when it settles and becomes fixed in position. Very soon there are secreted two long, coarse, entangling threads from just under the margin at the anterior end, which extend entirely over and around the insect.

Fig. 21.—(1) Development of purple scale; (2) beginning of the formation of the scale covering after the two, coarse enlarging threads have been secreted. Note the covering on the antennae. (3) Comparative size and shape of male (left), and female scales; (4) ventral view (left) showing eggs; (5 and 6) parasite, *Aspidiotiphagus citrinus* (Craw) within scales; (7) exit holes of parasite; (8) formation of covering after first molt. (From Bul. 226.)

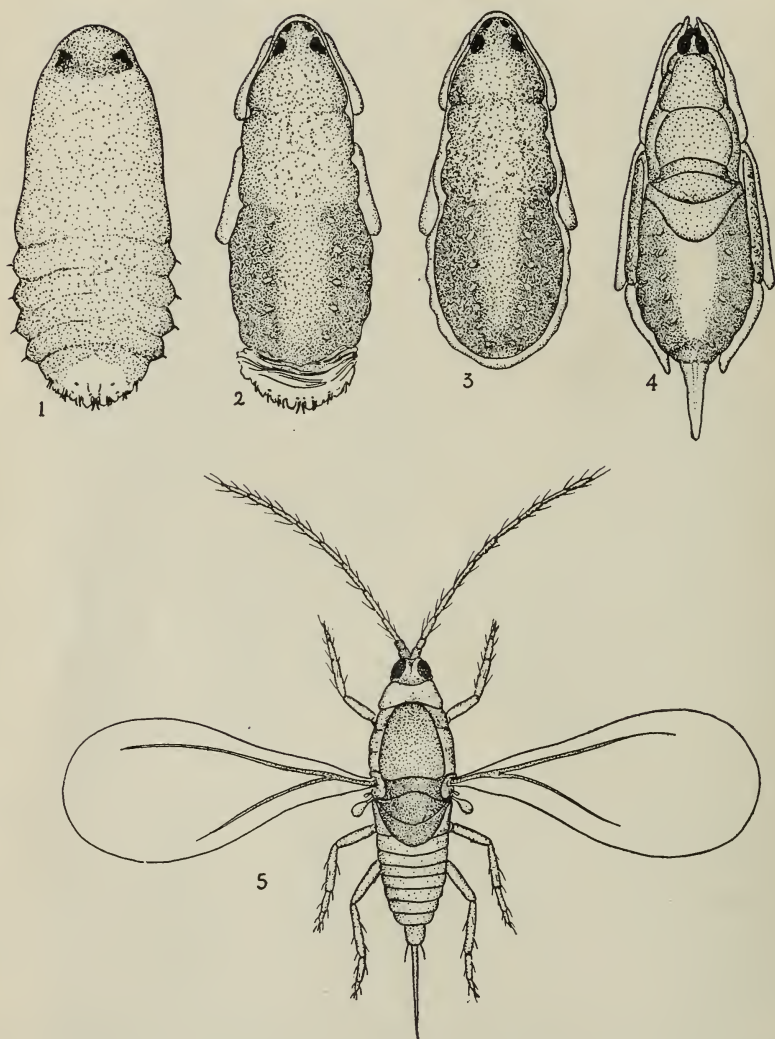


Fig. 22.—Stages in the development of the male purple scale. (1) Second stage; (2 and 3) prepupa, with second-stage cast skin still attached; (4) pupa; (5) adult. (From Bul. 226.)

These entangling threads remain until the insect is about half grown, probably serving as protection while the more permanent covering is being formed. When large numbers of the scale have recently hatched, these entangling threads give a general fuzzy effect. This fuzziness serves as a guide in applying control measures, for both fumigation and spraying are most effective on the half-grown stage.

After the two long protecting threads are formed, the insect begins the secretion of the permanent scale covering. This later secretion consists of very much finer threads and they cover the insect more completely (fig. 21, 2). The female undergoes two molts at intervals of about 3 to 4 weeks. The male, like that of the red scale, passes through four molts, with a prepupal and pupal stage (fig. 22), before issuing as a winged adult about 60 days from birth. The female, 70 or 75 days after birth, begins to deposit eggs and continues for 3 or 4 weeks. In most of the purple-scale area there are three full generations in a year with a partial fourth.

Parasites and Predators.—*Aspidiotiphagus citrinus* (Craw) (fig. 21, 5 and 6) is an internal parasite that attacks the scale in its second stage. Scales that have been parasitized have an exit hole in the posterior third of the scale covering.

Lindorus lophanthæ (Blaisd.) and *Scymnus marginicollis* Mann. are the commonest coccinellids attacking the purple scale. The beetles are about the same size ($\frac{1}{6}$ inch) and are black, but *Lindorus lophanthæ* has a metallic bronze-like luster, while *Scymnus marginicollis* is dull black.

GLOVER'S OR LONG SCALE, *LEPIDOSAPHES GLOVERII* (PACK.)

Glover's scale is related to the purple scale, but it is readily distinguished from the latter because it is much narrower and usually not so sharply curved as is often the case with the purple scale. It is not a citrus pest of importance in California and occurs only in a very restricted area in Orange and in San Diego counties.

GREEDY SCALE, *ASPIDIOTUS CAMELLIAE* (SIGNO.)

Greedy scale is sometimes found on old oranges (fig. 23), particularly those which may have remained on the tree from the previous year, or on the older tree-ripe lemons. It also occurs on the twigs, but it is of little consequence as a pest. It may be distinguished from the red or yellow scales because of its light gray color and much greater convexity. It occurs much more commonly on a long list of ornamental plants and shade trees than on citrus.

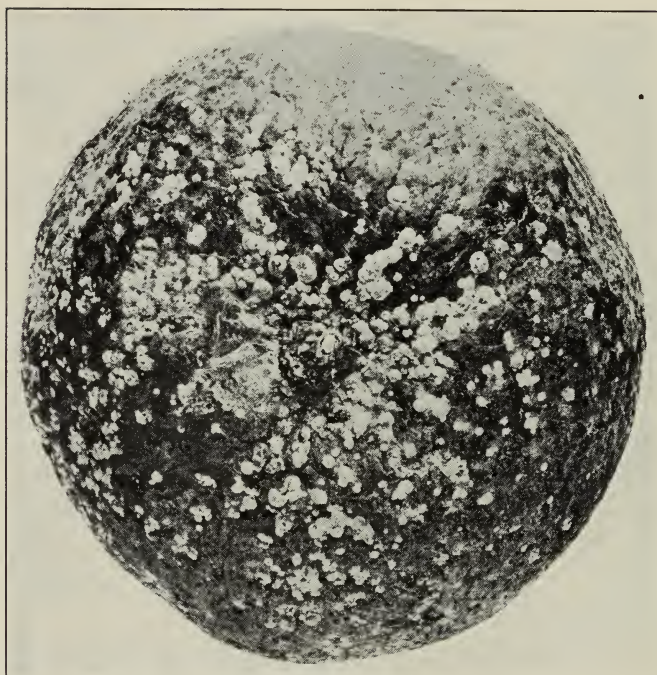


Fig. 23.—Orange infested with greedy scale, *Aspidiotus camelliae* (Sign.)



Fig. 24.—Mature black scale on orange twig. (From Bul. 223.)

IVY OR OLEANDER SCALE, *ASPIDIOTUS HEDERAE* (VALLOT)

Ivy scale occasionally occurs on lemons, and some growers call it "lemon-peel scale." Like the greedy scale, it is more commonly found on a wide range of ornamental plants. It is similar in color to the greedy scale, but is not so convex. The insect itself is small and pale yellow, while the greedy scale is large and yellowish-orange.

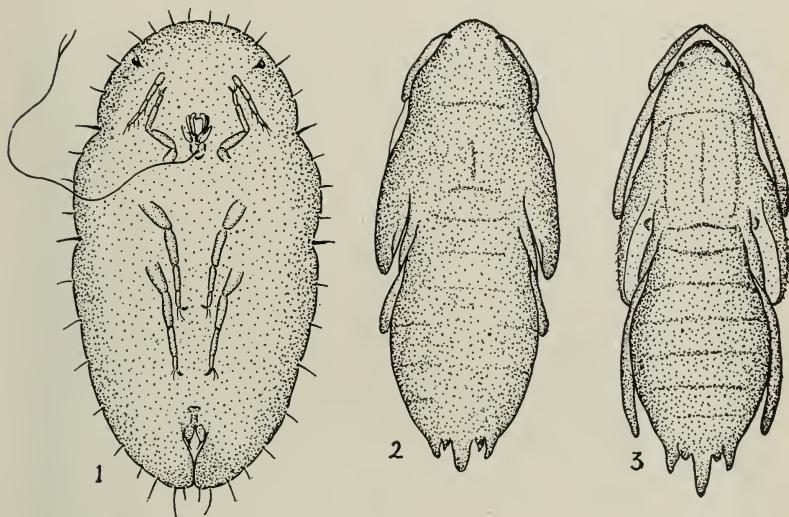


Fig. 25.—Stages of the male of the black scale: (1) second stage; (2) prepupa; (3) pupa. (From Bul. 223.)

BLACK SCALE, *SAISSETIA OLEAE* (BERN.)

The black scale (fig. 24) occurs more generally on citrus trees in southern California than any other scale insect. Such interior districts as Riverside and Redlands are not unfavorable to it, but it is not a pest on citrus in the chief citrus areas of the San Joaquin and Sacramento valleys, or in the Coachella and Imperial valleys. High summer temperatures definitely limit the distribution of this scale.

Food Plants.—Some of the preferred plants of the black scale, in fact more preferred than citrus, occur in close association with citrus plantings in southern California. Prominent among these are the olive and pepper trees, which so often occur as border trees; or, in the case of the olive, as adjacent plantings. These, together with the ornamental plants about dooryards, furnish a greater range of hosts than any of the other scale insects of citrus have.

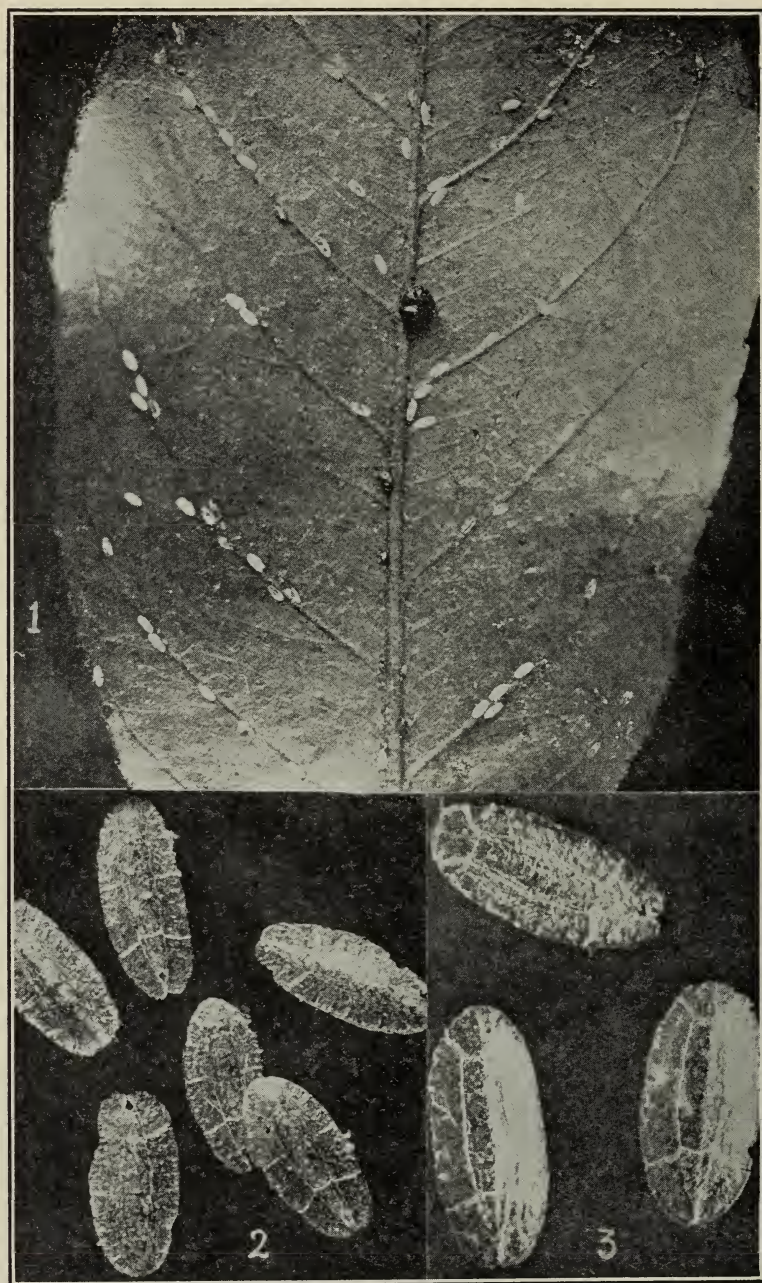


Fig. 26.—(1 and 2) Male puparia of black scale; (3) male puparia of hemispherical scale (same magnification as 2). (From Bul. 223.)

Injury.—The injury caused by the black and other unarmored scales is due not only to their feeding by extracting the juices from the plant, but also to the sooty-mold fungus, *Meliola camelliae* (Catt), which grows in the honeydew that these scales excrete. The honeydew falls upon the upper surface of the fruit and foliage, and such areas become more or less completely covered with the black sooty coating of the fungus.

Life History.—The eggs, which are pearly-white to pink, according to their age, may be seen upon lifting the mature female scale. The number will range from a few hundred to 4,000, according to the size of the insect, the average being about 2,000. The light-brown young larvae appear after the eggs have been deposited 15 or 20 days, and crawl about often for a day or two before settling. The first molt occurs from 1 month to 6 weeks after birth, and the second molt from $2\frac{1}{2}$ to 3 months from birth.

Up to the time of the first molt, there is no distinguishable difference between the male and female. After the first molt the male becomes much more elongate (fig. 25), with eyes visible in the latter part of this stage. It will be noted that in the case of the armored scales the covering under which the male transforms is secreted from the beginning. The development of the male through the delicate prepupal and pupal stages could not very well take place without some protection also, but the black scale has no armor. So, in the second stage of the male black scale, a puparium (fig. 26) is formed, consisting of a transparent glassy-like covering, under which transformation to the prepupal, pupal, and adult stages takes place.

The male of the black scale is found only occasionally. Reproduction ordinarily occurs without fertilization.

Seasonal History.—There is usually but one complete generation of the black scale in the year, over much of the area where the scale occurs. In the interior areas there may be black scale out of the usual stages on occasional sucker growth on lemons, on young grapefruit trees, or on pepper trees. On practically all of the citrus plantings, however, there is a very uniform development in this area, and it constitutes a condition known as the "normal hatch."

In the coastal area there may be an overlapping of two generations. Such a condition is known as "irregular hatch." It is well known that high temperatures constitute one of the most important factors governing the distribution of the black scale. High temperatures, in the writer's opinion, also inhibit the development of the black scale; this would account for the slow and uniform development of the scale during the summer and fall in the interior districts. The occasional out-of-

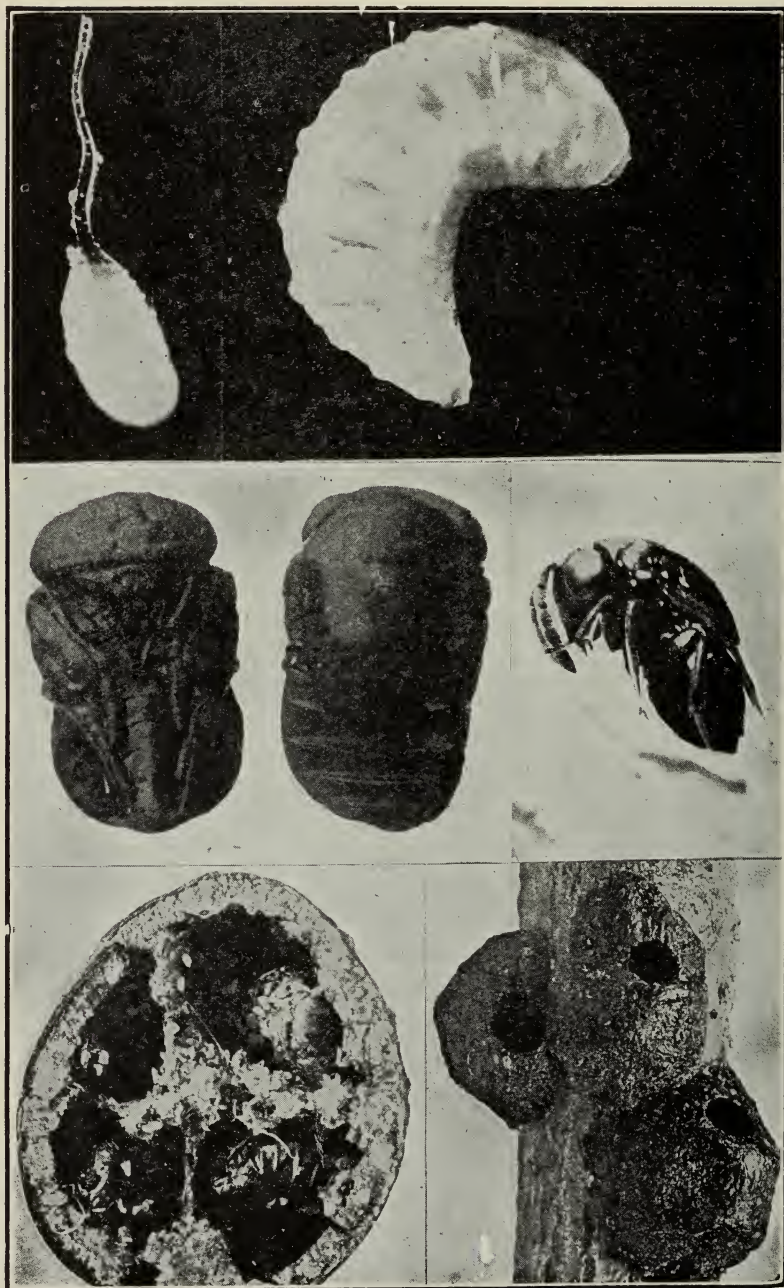


Fig. 27.—Top, egg and larva of *Scutellista*. Middle, left, pupa; right, adult. Bottom, left, inverted black scale, showing four *Scutellista* pupae; right, exit holes. (From Bul. 223.)

season scale in this area, as indicated above, is probably due to the food supply. In Orange County, for example, there is a pronounced hatch in July, when fumigation may be carried on, and another hatch in the winter, when fumigation may be carried on in February; and there are still other groves where the black scale may be in condition for treatment at different times between July and February.

Parasites and Predators.—*Scutellista cyanea* (Motsch.) and *Metaphycus lounsburyi* (How.) are two of the commonest and most effective of the parasites attacking the black scale in California. *Scutellista* (fig. 27) is an egg parasite and in the larval stage feeds externally on the



Fig. 28.—*Metaphycus lounsburyi* (How.). (After Smith and Compere.)

eggs beneath the parent scale. The adult *Scutellista* emerges through a hole which it cuts out of the body wall of the scale. Usually one *Scutellista* occurs beneath a single scale, but there may be two, sometimes three, or very rarely four.

Metaphycus lounsburyi (How.) (fig. 28) attacks the more mature scales, the eggs being deposited within the body of the scale and suspended in the fluid contents by a long pedicel, the tip of which projects to the outside. The younger stages of the larva depend upon the pedicel of the egg as a respiratory tube, but in the last stage this connection is severed and the larva is equipped to breathe air directly. Black scales parasitized by this species may be distinguished by the fact that the exit holes are smaller and more numerous than those due to *Scutellista*.

The introduction of the species *Metaphycus lounsburyi* a few years ago gave great promise of being a very important check on the black scale in "irregular hatch" areas, until its work was seriously affected

by a secondary parasite, *Quaylea whittieri* (Timb.). However, it is still of considerable value, attacking certain stages and thus bringing about a more uniform development of the scale.

Smith and Compere (1931) list a total of 35 species of parasites that attack the black scale in various parts of the world.

Of the predators, *Rhizobius ventralis* (Er.) is the most important. The larva of *Rhizobius* is $\frac{1}{5}$ inch long, with the dorsal surface entirely black and the ventral surface dull gray. The adult is $\frac{1}{8}$ inch long, with shiny black elytra covered with gray hairs.

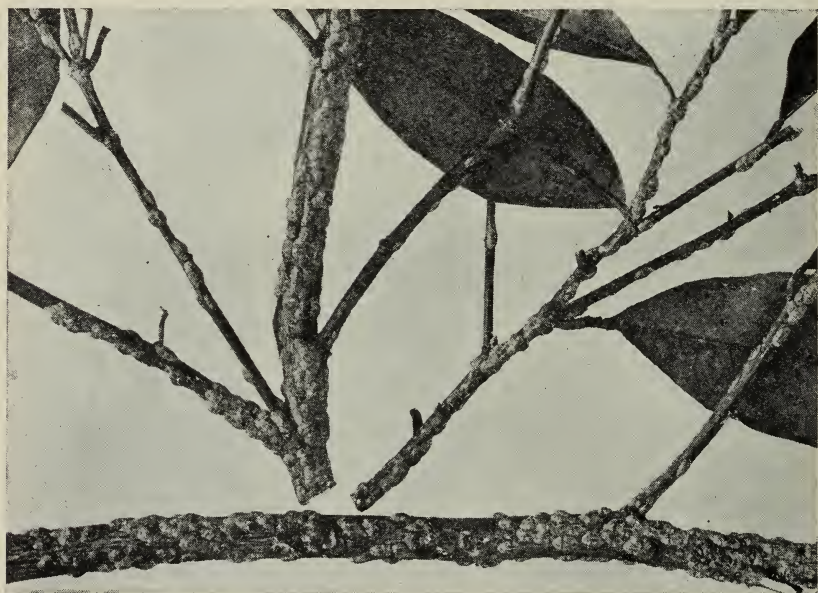


Fig. 29.—Citricola scale on orange twigs. (From Bul. 255.)

CITRICOLA SCALE, COCCUS PSEUDOMAGNOLIARUM (KUW.)

The citricola scale (fig. 29) is the most injurious of the scale insects attacking citrus in the San Joaquin and Sacramento valleys. In southern California the citricola scale occurs in the Bardsdale-Fillmore and Ojai sections in Ventura County, from Claremont and Pomona eastward to Redlands, south to Riverside and Corona, and in the Placentia section of Orange County.

Identity.—The citricola and soft brown scale are sometimes confused and, where there are but a few specimens, this may be expected. However, there are many important differences, not only in the scales themselves but in the character of the infestations. The soft brown scale

is usually confined to single twigs or portions of the tree, while the citricola scale occurs more or less generally over the entire tree or grove. Since there is but one generation of citricola scale a year, all of the scales seen in any infestation will be of the same size; whereas with the soft brown scale there are three or four generations a year and there may be different-sized scales on the same twig or leaf. There are also some differences in the coloring. The citricola scale, when it approaches maturity, is gray, while the soft brown scale is more of a brown color. The young of the citricola scale are very flat and much more transparent than the young of the soft brown scale. The citricola scale lays eggs, while the soft brown gives birth to young; the citricola scale invariably matures on the twigs, while some of the soft brown scale may mature on the leaves.

Injury.—Injury caused by the citricola scale is due to the extraction of juices from the plant, and also to the copious excretion of honeydew in which grows the sooty-mold fungus. Where infestations are severe, the tree is unable to bear its usual crop.

Life History.—The eggs are deposited by this scale to the number of 1,000 to 1,500, over a period of 30 to 40 days. Upon hatching, the young may remain beneath the parent scale from a few hours to a day or two, according to the temperature. The young crawl about actively for about a day, after which they settle largely upon the under surface of the leaves. In the case of severe infestations, a great many also establish themselves upon the upper side, and on the more tender twigs. The first molt occurs approximately one month after settling, and the second or last molt about one month after the first molt. The discarded skins may be detected as cornucopia-like objects, not unlike a bit of thread or lint, which often remain attached to the posterior end of the scale.

Seasonal History.—The eggs are deposited by this scale mostly in May or June, some, of course, being deposited during the latter part of April and others extending into July. From the time of hatching until the following spring (about March) the scales are largely on the leaves and tender twigs. During this time they have grown very slowly, but after they migrate to the twigs, in the early spring, they grow very rapidly and are mature by the latter part of April.

Parasites and Predators.—The citricola scale is not attacked by parasites as extensively as its relative, the soft brown scale. Most of the parasites working on the citricola scale at present attack the scale when it is still small, as *Metaphycus luteolus* (Timb.), *Coccophagus scutellaris* (Dalman), and *C. lecanii* (Fitch). Some of the species of coccinellids that feed upon black scale also feed upon citricola scale.

SOFT BROWN SCALE, COCCUS HESPERIDUM LINN.

The soft brown scale is usually limited to a part of the tree, or a few trees, and very rarely infests the entire grove. Infestation is usually of short duration, owing in most cases to the work of parasites. Where the Argentine ant occurs in large numbers, the scale may make considerable headway and do damage to the trees. Injury is done by feeding and by the sooty-mold fungus, which grows in the honeydew that is given off. It attacks the smaller twigs and leaves.

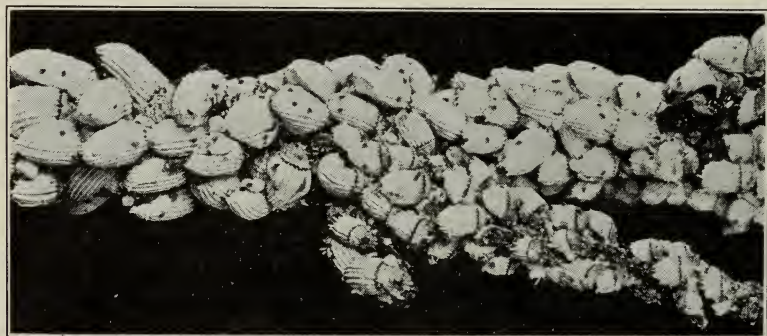


Fig. 30.—Cottony cushion scale on orange twig.

Life History.—No eggs are deposited by this scale, the young being born as in the case of the red scale. They molt twice, come to maturity, and produce young in 65 days during the summer months. Thus there may be several generations a year, whereas the citricola scale has but a single generation. For other differences between this species and the citricola scale, see page 44.

Insect Enemies.—The same parasites as those mentioned under “Citricola Scale” attack the soft brown scale.

COTTONY CUSHION SCALE, ICERYA PURCHASI MASKELL

The large fluted cottony mass so characteristic of the cottony cushion scale (fig. 30), is secreted only by the female when it is full grown. It is in this cottony mass that the eggs, numbering 500 to 800, are deposited.

The young settle upon the leaves and twigs and also along the midrib and veins of the leaf. The reddish-colored larva with black legs may be easily distinguished from the cast skins, which are yellowish-white. From 3 to 4 months are required for the complete life cycle, so that there are about three generations in a year. If an infestation is not checked, portions of the tree may be killed in a very short time.

Insect Enemies.—This scale, which was an introduction from Australia in 1868, threatened the citrus industry in the early days and was a major pest until the introduction of the predator vedalia, *Rodolia cardinalis* (Muls.) in 1889. This was the first eminently successful introduction of one insect to prey upon another, and the result served as an inspiration for much of the biological control work that has been carried on since. The cottony cushion scale at the present time is a pest of little importance, although small infestations appear from time to time. These infestations are usually of short duration, since the vedalia generally finds them and brings them under control. Occasionally, however, an infestation will persist and small colonies of vedalia are then distributed.

In addition to vedalia, the cottony cushion scale has another important enemy, the dipterous parasite *Cryptochaetum iceryae* (Will.). This is a small black fly with greenish-black reflections, the larva of which lives within the scale. The adult emerges from an exit hole which characterizes such parasitized scales.

HEMISPHERICAL SCALE, *SAISSETIA HEMISPHAERICA* TARG.

The hemispherical scale (fig. 26, 3) is of little consequence as a citrus tree pest, although it is found in certain sections such as Santa Barbara and San Diego counties. It is a scale that is easily distinguished, being hemispherical in shape, brown in color, of smooth shiny surface, flared at the margin, and without the letter H which occurs on the black scale, its nearest ally on citrus.

MEALYBUGS

(Class Insecta, order Homoptera, family Coccidae)

There are five species of mealybugs (fig. 31) found on citrus trees in California: the citrus mealybug, *Pseudococcus citri* (Risso); the citrophilus mealybug, *P. gahani* Green; Baker's mealybug, *P. maritimus* (Ehr.); the long-tailed mealybug, *P. longispinus* (Targ.); and the Japanese mealybug, *P. krauhniae* (Kuw.).

The first four species may be readily distinguished in figure 31. The chief difference in the external appearance of the different species of mealybugs is in the waxy covering and the filaments of the same material around the margin of the bodies, particularly at the posterior end. The posterior filaments of the long-tailed mealybug are longer than the body, and slender; those of Baker's mealybug are slender but much shorter than the body. In the citrus mealybug the filaments are short and thick, the posterior ones being a little longer than the lateral ones.

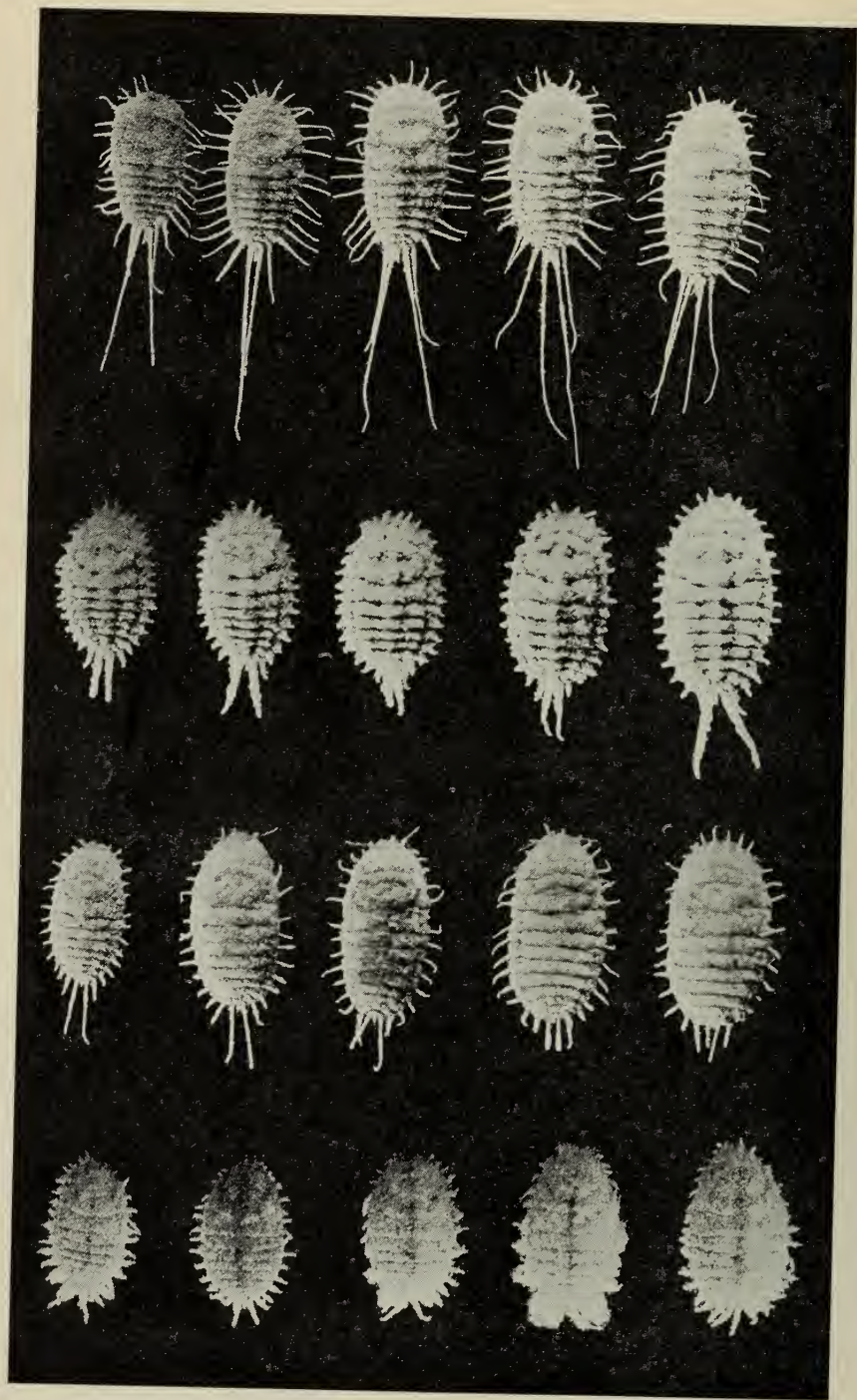


Fig. 31. (See caption on opposite page.)

In the citrophilus mealybug there are usually two posterior filaments that are longer and stouter, tapering toward the tip. Also, in this species the waxy covering is not uniform, but is broken by four small areas on each body segment which are sparsely covered, giving the appearance of four longitudinal lines. The body fluid of this species is also dark in color, while it is light-colored in the three previous species.

The Japanese mealybug, *Pseudococcus krauhniae* (Kuw.) is limited to a small area in the Ojai Valley in Ventura County. The Japanese mealybug is similar to the citrus mealybug in its covering and filaments; but it is much larger when mature and the body fluid is dark colored like that of citrophilus.

Another species of mealybug, while it does not attack citrus, is likely to concern the citrus grower because it is very common on a variety of plants about the home. This is the Mexican mealybug, *Phenacoccus gossypii* Towns. and Ckll. It may be distinguished from the other species by its covering of coarse, granular wax, central longitudinal ridge, grayish body color, and elongated compact egg sac.

Formerly the species *citri*, the citrus mealybug, was the only one of importance on citrus in California, and it often did damage in certain localities of the citrus area, particularly in Ventura, San Diego, and Los Angeles counties. In 1913 the citrophilus mealybug, a new species, was found at Upland, the original infestation covering about 20 acres. Since that time the citrophilus mealybug has spread rapidly over the citrus area of southern California until it had covered about 75,000 acres. This mealybug became a much more serious pest, because of its more general distribution, than the citrus mealybug.

The citrophilus mealybug thrives best in the coastal section and has never been a very serious permanent pest in the more interior sections of southern California.

The remaining two species are never found in very large numbers on citrus trees. The long-tailed mealybug is found most commonly in Santa Barbara County, while Baker's mealybug occurs most commonly in Los Angeles and Orange counties.

Injury.—Mealybugs injure the trees in much the same way as the unarmored scales, such as the black scale. They extract the juices from the plant and also secrete large quantities of honeydew in which grows the sooty-mold fungus. This fungus causes a black covering on the foliage and fruit, which interferes with the normal functions of the

Fig. 31.—Mealybugs of citrus trees. Top, long-tailed mealybug, *Pseudococcus longispinus* (Targ.); second row, citrophilus mealybug, *P. gahani* Green; third row, Baker's mealybug, *P. maritimus* Ehr.; fourth row, citrus or common mealybug, *P. citri* (Risso). (From Bul. 258.)

plant. In addition, mealybugs may cluster around the pedicel of the fruit and cause young oranges or lemons to drop in the early spring, and mature Valencias late in the season. The masses of white, cottony secretion enveloping the eggs and occurring over the tree and fruit, also add to the detrimental effect of mealybugs.

Life History.—The life histories of the different species of mealybugs are similar and may be grouped together for this discussion.

As many as 800 eggs are deposited in cottony fibers secreted for the purpose, over a period of 10 to 20 days. The young hatching from the eggs crawl about and, unlike scale insects, maintain their power of locomotion throughout their existence, except that the females are usually stationary after egg-laying begins, and the males are fixed during the pupal period. The young, in general appearance, are like the adults except that they are smaller. The female undergoes three molts, while the male, like the male of scale insects, passes through a total of four molts. There may be four generations during the course of a year.

Parasites and Predators.—Mealybugs are attacked by a large number of parasites and predators. The most important predator has been *Cryptolaemus montrouzieri* Muls., which was formerly reared in large numbers by insectaries established in all of the counties of southern California. This beetle was reared upon mealybugs which were grown on potato sprouts in the insectary. Usually ten beetles were liberated per tree, though in the case of heavy infestations a larger number was liberated if there was an ample supply. This method of control proved to be effective, although certain conditions occasionally favored the development of the mealybug and not the beetle, resulting in a temporary increase of infestation.

The fact that the citrus mealybug is not the pest it was formerly, before its place was usurped by the citrophilus species, is probably due to the introduction of the Sicilian parasite, *Leptomastidea abnormis* (Girault), as well as to the liberation of large numbers of *Cryptolaemus* for the control of the citrophilus mealybug.

The chief dependence for control has been the biological method, since the mealybug is difficult to kill by fumigation and is not well controlled by spraying, on account of rapid multiplication after spraying. A few years ago, H. S. Smith, in charge of the biological control work for the University of California, sent an entomologist, Harold Compere, to Australia to determine if the citrophilus mealybug might not be found there, and, if so, to collect such parasites as attack it. The work was eminently successful and five species of parasites and predators were introduced and established. Of these, two in particular, *Cocco-*

phagus gurneyi (Compere) (fig. 32) and *Tetracnemus pretiosus* Timb. (fig. 33) have been especially effective. At the present time these Australian parasites are keeping the citrophilus mealybug well under control and, if this continues, there will be no occasion for continuing the propagation of *Cryptolaemus* at the different insectaries, at least for the control of this species.

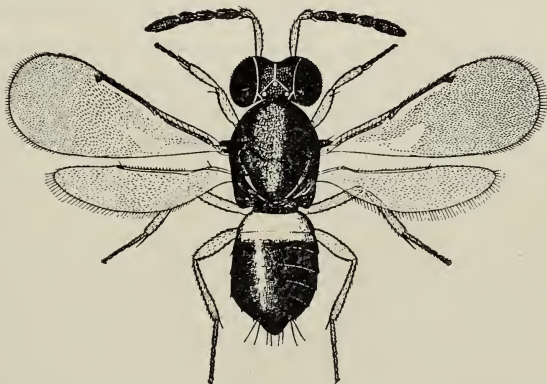


Fig. 32.—*Coccophagus gurneyi* Compere, parasite of citrophilus mealybug.

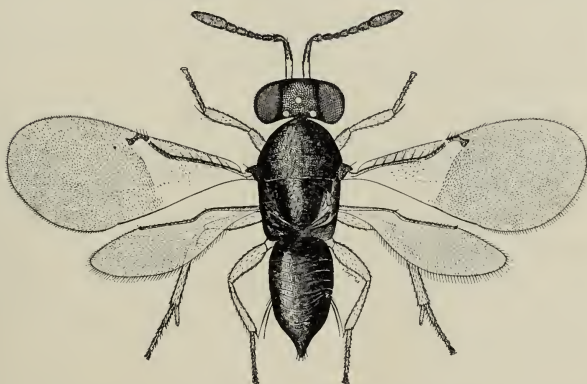


Fig. 33.—*Tetracnemus pretiosus* Timberlake, a parasite of citrophilus mealybug. (From Hilg. Vol. 6, No. 17.)

WHITE FLIES

(Class Insecta, order Homoptera, family Aleyrodidae)

CITRUS WHITE FLY, *DIALEURODES CITRI* (ASHM.)

The citrus white fly is one of the important citrus insects of the Gulf states. It was discovered at Marysville and Oroville, California, in 1907, and has since been found at Sacramento and some other points in the Sacramento Valley in addition to the two places mentioned. There

have been three or four small outbreaks of the fly in southern California, but those infestations have apparently been eradicated, or are in the process of eradication, so that it does not yet occur in commercial citrus plantings.

The white fly is related to the scale insects and, like them, is scale-like and fixed to its host, except in the first stage, when it is an active crawler, and in the adult winged stage. The greatest difference is that while only the male of scale insects becomes winged and capable of flying, both sexes of the white fly become winged. The fact that the females are winged enables them to spread much more rapidly than scale insects. Consequently they are difficult to keep under control, because of the rapid infestation that is likely to occur from untreated citrus trees or other host plants.

Life History.—There are four stages in the development of the white fly: egg, larva, pupa, and adult. The egg is oval, pale yellow, and $1/100$ inch long. When numerous the eggs give the leaves the appearance of being covered with pale yellow powder, since the individual eggs are scarcely visible to the unaided eye. They are laid on the under side of the leaves and are fastened by a short stalk. The eggs, numbering about 100, are laid in 8 or 10 days and hatch in 10–12 days into yellow, flat crawlers that avoid the direct light and settle after a few hours on the under surface of the leaves.

During the first molt the legs and antennae are lost. The larva is flat, transparent, and scale-like, and has transverse lines. After two other molts the fourth-stage larva, or pupa, appears. This stage is different from the others. It takes much less food in this stage, is thicker, and the outline of the adult white fly takes form. This stage corresponds to the pupal stage of most insects. Finally the pupal cases split crosswise on the back and the mealy-winged white flies ($1/15$ inch long) of both sexes emerges.

In Florida there are three main generations in a year. The spring brood of adults is at its maximum in March, the summer brood in June, and the fall brood in the latter part of August and first part of September.

Control.—Since a grove may be infested from neighboring groves at each flight of the adult flies, an oil spray is applied in Florida for the spring and fall broods, the summer brood usually being controlled by entomogenous (insect-feeding) fungi. The spraying is timed by the disappearance of the flight of the flies, plus about a 10-day interval in order to allow the eggs to hatch. The time for spraying in Florida is during May and the last part of September.

CICADAS

(Class Insecta, order Homoptera, family Cicadae)

In the Coachella Valley some injury is done each year by a species of cicada (*Tibicen cinctifera*), which makes egg punctures in the twigs of grapefruit trees.

Upon hatching, the nymphs make their way to the ground, where they feed upon the roots of whatever plants may be growing in the grove, including those of the grapefruit tree. The nymphs require two years for their development. Because of their slow feeding, the injury to the roots of the tree is not important, except when the nymphs are present in large numbers.

There have been complaints of root injury by this insect on some of the other crops in the Coachella Valley, such as asparagus. The only control measure available on grapefruit or other species of citrus is to cut off and destroy the twigs where the egg punctures occur, before the eggs have hatched.

PLANT BUGS

(Class Insecta, order Hemiptera, family Coreidae)

WESTERN LEAF-FOOTED PLANT BUG, *LEPTOGLOSSUS ZONATUS*
(DALLAS)

The western leaf-footed plant bug is about $\frac{3}{4}$ inch long, with a zigzag light stripe across the wings and the enlargement of the hind leg which resembles a leaf and suggests the common name (fig. 34). The nymphs are red and black.

Another related species, *Leptoglossus phyllopus*, occurs in Arizona and New Mexico.

In California the western leaf-footed plant bug is primarily a pest of pomegranates. Its attacks on citrus, which have been severe in some cases, have been limited to citrus adjoining or near pomegranates in the Imperial Valley.

The injury to citrus is due to the sucking of the juices from the fruit. When a dozen or more attack a single orange, grapefruit, or tangerine, the fruit dries out and drops from the tree. This insect spreads a disease-causing fungus, *Nematospora coryli*, in pomegranates, and the same fungus causes a slight staining of the orange where infection has occurred through the punctures.

Thus far, in the Imperial Valley, there are two ways in which this insect may be handled. One is the destruction of its chief host, the pomegranate, where this fruit is not considered of much value; and the other, which has been successfully practiced, is the maintenance of a



Fig. 34.—Western leaf-footed plant bugs on orange.

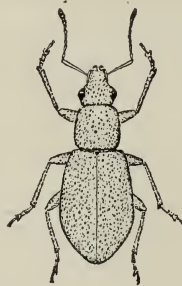


Fig. 35.—Fuller's rose weevil. (From Bul. 214.)

flock of turkeys to feed upon the bugs. The bugs are shaken from the pomegranates in the early morning and are thus available for the turkeys. A flock of turkeys is thus partially maintained, and at the same time serious loss to the pomegranates and practically all loss to nearby citrus from these bugs is avoided.

BEETLES AND WEEVILS
(Class Insecta, order Coleoptera)



Fig. 36.—Work of Fuller's rose weevil on orange leaves. (From Bul. 214.)

FULLER'S ROSE WEEVIL, *PANTOMORUS GODMANI* (CROTCH)
(Family Curculionidae)

Fuller's rose weevil (fig. 35) is about $\frac{1}{3}$ inch long and grayish-brown. The body tapers toward the head, which ends in a short, broad snout or beak. The eggs are laid in masses of from 10 to 60, in crevices

on the citrus trees, or sometimes under the button of the fruit. The larvae live on the roots of the citrus tree, provided there are no other plants available, which is usually the case in a clean-cultivated grove. The injury to the roots is due to the shallow surface channels that are eaten out. When the weevil larvae are abundant, many of the roots are



Fig. 37.—Work of *Diabrotica* on orange leaves. (From Bul. 214.)

thus affected. The larva is a legless, yellowish-white, curved grub about $\frac{1}{5}$ inch long.

The injury caused by the adult beetle is characterized by the irregular areas eaten away around the margins of the leaf (fig. 36). In large trees this injury occurs mostly in the lower part of the tree. It is on young or recently budded trees that the beetle does the most injury, particularly where these occur as interplants or have replaced an old orchard.

Young trees, where the foliage is some distance above the ground, may be protected by 4-inch cotton bands. The band is tied around the bottom and the upper part is pulled down over the string. The beetles are thus prevented from crawling up the trunk, and, since they have functionless wings, they cannot fly. The beetles should be shaken from the trees at the time of applying the band. In the case of rains or overhead sprinkling, the cotton in such bands becomes matted and thus its effectiveness is lost. Tanglefoot bands, the tanglefoot put over a coated area of high-boiling-point paraffin, may also be applied.

If the attack is severe on old trees, where the foliage is in contact with the ground, the lower part of the tree may be dusted with barium fluosilicate or cryolite.

DIABROTICA SORER LEC.

(Family Chrysomelidae)

Diabrotica is the common green beetle, with 12 black spots, that may be seen on many different plants. It occasionally does considerable damage to the tender, growing shoots of the orange and to the young fruits. In such cases the beetles swarm in from other surrounding crops, such as grain, after they have become dry in the spring. Lemon foliage is rarely attacked.

This beetle may eat away parts of the epidermis on the leaves (fig. 37) so that the leaves have a more or less ragged effect. On the fruit, the beetle causes small scars that sometimes result in a distorted growth.

The larva is slender, yellowish-white, has a dark head, and is not curved and grub-like as in the case of the larva of Fuller's rose weevil. *Diabrotica* larvae feed on the roots of various plants, particularly grasses and weeds, but they are not injurious to the roots of citrus trees.

Dusting the trees with barium fluosilicate or cryolite is the most satisfactory treatment.

FRUIT FLIES

(Class Insecta, order Diptera, family Trypetidae)

MEDITERRANEAN FRUIT FLY, *CERATITIS CAPITATA* WIED.

The Mediterranean fruit fly is an important pest of oranges in the Mediterranean region, and in South Africa and Australia, where conditions are similar to those of much of the citrus area of California. The adult fly is a little smaller than the house fly. There are two white bands on the yellowish abdomen; yellow, black, and brown markings on the wings, which are normally held in a drooping position and there are black areas on the back (fig. 38).

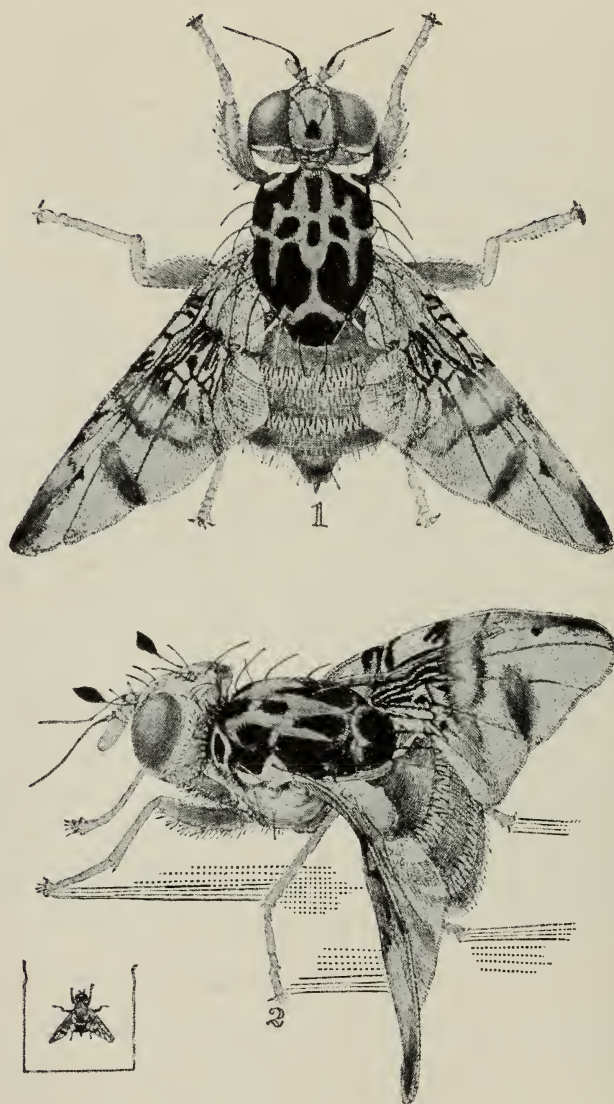


Fig. 38.—Mediterranean fruit fly, *Ceratitis capitata* Wied. Female above; male below. Characteristic position of wings is shown in lower figure. (From Cir. 315.)

The eggs are white, $\frac{1}{27}$ inch long, and pointed at each end. They are deposited in a cavity of the rind or beneath the skin of the fruit.

The larva (fig. 39 A) when full grown, is a little over $\frac{1}{4}$ inch long and ordinarily of a cream color. It is sluggish in its movements, but when full grown it has the habit of arching its body and from this position is capable of springing as far as 4 or 5 inches. The posterior spiracles may be seen as six oval-shaped, brown structures. They are arranged in two groups of three, set opposite one another, and are flush with the surface, rather than on the end of short stalks as is the case with certain dipterous scavenger larvae. The larvae burrow directly into the pulp and remain for 10 days to 3 weeks, when they go into the soil for pupation.

The pupae are like swollen grains of wheat, of a straw to dark-brown color, and transversely ringed.

The adult fly, upon emerging, feeds on fruit and plant juices for several days before depositing eggs. This is the vulnerable period in the life cycle, when it may be killed by a poisoned-bait spray.

There are more than 100 different hosts, but the preferred fruits are the peach, nectarine, orange, grapefruit, apricot, and pear; these are not attacked until a certain stage of maturity is reached. Infested fruits are detected by a small slit in the surface, which afterwards enlarges as the larvae continue feeding.

Conditions favorable to the fruit fly are found in regions of mild winters and where there is a sequence of host fruits; such conditions are well represented in much of the California citrus area. The fly, however, does not occur in California.

MEXICAN FRUIT FLY, *ANASTREPHA LUDENS* (LOEW)

The Mexican fruit fly (fig. 40) is an important pest of citrus, mangoes, and other fruits of Mexico. Its life history and habits are in general similar to that of the Mediterranean fruit fly. The larva is larger than that of the Mediterranean fruit fly, and the tubercles (fig. 39 A, 2) are bead-like instead of having longer projections as in the latter species.

In 1927 infestations of this species were found in the lower Rio Grande Valley of Texas. Because of the eradication campaign immediately inaugurated it was not discovered again until 1929, when it reappeared from Mexico and was again eradicated. The fact that this species can thrive in the lower part of Texas is a reasonably certain indication that it could become established in parts of citrus areas in California. It has not, thus far, been found in California.

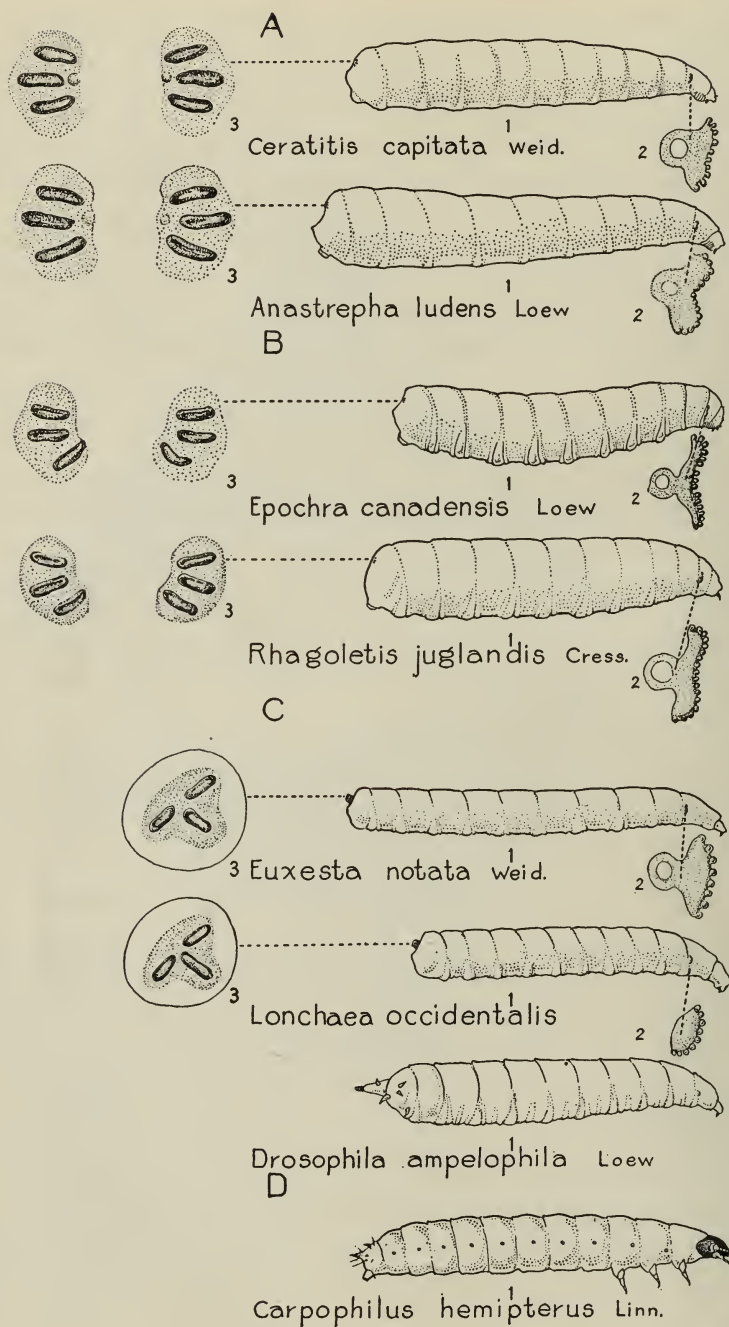


Fig. 39. (See caption on opposite page.)

ORANGE WORMS AND CUTWORMS

(Class Insecta, order Lepidoptera)

ORANGE TORTRIX, *TORTRIX CITRANA* FERN.

(Family Tortricidae)

The larva of the orange tortrix makes small burrows in the rind of the fruit, usually where two fruits or a leaf and fruit are in contact.



Fig. 40.—Mexican fruit fly, *Anastrepha ludens* (Loew): (1) male; (2) female; (3) pupa; (4) larva. (From Cir. 315.)

Such burrows not only mar the fruit but furnish a source of infection for decay organisms. Oranges that may show no external evidence, aside from a small burrow, may be badly broken down by interior decay

Fig. 39.—*A*, Larvae of fruit flies not in California: the Mediterranean fruit fly and the Mexican fruit fly. *B*, Larvae of fruit flies in California: the currant fruit fly, *Epochra canadensis* (Loew) and the walnut husk fly, *Rhagoletis completa* Cresson (*R. juglandis*). *C*, Larvae of scavenger flies found in decaying fruits in California: *Euxesta putricola* Cole (*E. notata* Weid.), *Lonchaea occidentalis* Mallick, and *Drosophila ampelophila* Loew. *D*, Larva of a scavenger beetle, *Carpophilus hemipterus* (Linn.), found in decaying fruits in California. (From Cir. 315.)

by the time they reach the consumer. The burrows in the fruit also tend to make the fruit drop prematurely and such dropped fruit is not accounted for in the packing-house records.

Life History.—The eggs are laid usually on the underside of the leaves or on the fruit. They are laid in masses of from 10 to 35 and overlap one another like fish scales. The individual egg is greenish-yellow, $\frac{3}{100}$ inch in diameter, disk-shaped, and distinctly marked with a hexagonal network. The total number of eggs laid by a single moth varies from 50 to 75. Hatching occurs in 10 days to 2 weeks.

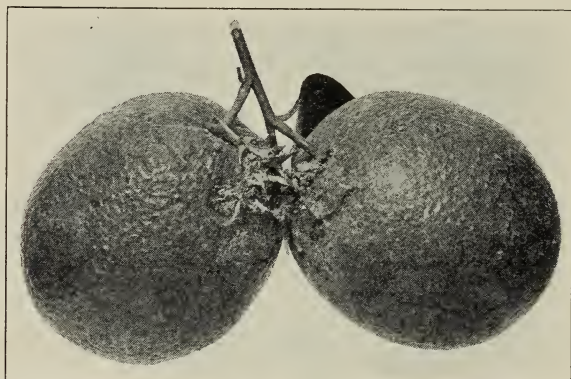


Fig. 41.—Nest of *Holcocera* between fruits.

The young larva feeds by making small burrows, but later confines its work to a single burrow. The larvae work in the navels in the fall and early winter, and also in the Valencias in summer. The full-grown larva is $\frac{1}{2}$ inch long, straw to greenish-white in color, and has a light-colored head.

The adult is a buff-colored moth, $\frac{1}{2}$ inch long and with the hind margins of the wings forming a shallow V. Control measures are suggested on p. 63.

HOLCOCERA ICERYAELLA (RILEY)

(Family Blastobasidae)

The injury caused by *Holcocera* is somewhat similar to that of the orange tortrix. It frequently eats a hole through the rind and into the pulp, but more commonly it makes shallow burrows or scarred areas, around which a brown leathery spot often develops. *Holcocera* larvae are most injurious to ripe oranges in the summer from April to Novem-

ber, and consequently are of importance only in connection with Valencia. The larvae are usually hidden in old flower parts and other débris (fig. 41).

The *Holcocera* larva is dark gray, with a black head; it is sluggish in its movements and about three-fourths the size of the tortrix larva. The characters given will readily distinguish the larva of *Holcocera* from that of the tortrix.

Parasites (*Apanteles* sp. and *Hormius* sp.) are often of value in checking the injury by the tortrix larvae, but they are of no importance in connection with *Holcocera* larvae (fig. 41).

CONTROL OF TORTRIX AND HOLCOCERA

There is no satisfactory and economical control for orange worms that is practiced at the present time. Barium fluosilicate or cryolite, applied as a dust, would be the most promising materials for further trials, where the severity of the infestation warrants.

CUTWORMS

(Family Noctuidae)

Cutworms, or the larvae of noctuid moths, sometimes do injury to orange fruits by burrowing into them during the early spring before or shortly after the covercrop is turned under. The holes are about the size of a lead pencil and occur mostly on the fruits low down on the tree, particularly where the foliage is in contact with the ground. The injury is rarely sufficient to warrant control measures. The broadcasting of poisoned bran mash under the trees is a feasible treatment.

ANTS

(Class Insecta, order Hymenoptera)

ARGENTINE ANT, IRIDOMYRMEX HUMILIS MAYR.

The Argentine ant may occur in citrus orchards where any of the insects that give off honeydew are present, because this substance is an important source of food. Where insects, such as the mealybug and the soft brown scale, are controlled chiefly by insect enemies, the relation of the ant to the pest is especially important.

The Argentine ant worker is dark brown and without odor when crushed. The workers move rapidly up and down the infested tree and, when numerous, in a very definite column. There are many nests located in the soil, usually near the base of the tree.

Control.—The standard method of control of the Argentine ant consists of a weak poisoned bait, which when carried to the queen in her nests destroys the source of the colony. The formula is as follows:

- 11 pints water
- $\frac{1}{4}$ ounce tartaric acid
- $\frac{1}{3}$ ounce benzoate of soda
- 12 pounds granulated sugar
- $\frac{3}{4}$ ~~8 3/4~~ ounces chemically pure sodium arsenite
- 2 pounds strained honey

Heat the water until lukewarm. Add the tartaric acid and stir until dissolved. Add the benzoate of soda and stir until dissolved. Slowly add the granulated sugar, stirring constantly until dissolved. Note the exact height of the liquid in the container, cover and boil slowly for 40 minutes. Add water to equal that evaporated at the end of each 20 minutes. To 1 pint of lukewarm water add the sodium arsenite and stir until completely dissolved; then add this to the syrup and stir well. Finally stir in the honey.

The above bait was formerly placed in paraffined paper cups which were attached to the trunk of the tree. The present practice favors the use of a special aluminum cup, which may be cleaned and refilled and lasts indefinitely. The aluminum cup also prevents the leakage and consequent injury to the tree that sometimes occurs with the paper cup.

FIRE ANT, *SOLENOOPSIS GEMINATA* (FABR.)

The workers of the fire ant are pale yellow or reddish, with black abdomen, and they do not occur in such large numbers as the Argentine species; but, unlike the latter species, the fire ant attacks the young citrus tree directly. They are attracted by small drops of gum which ooze from the bark. They also bite off chips of the outer bark, which fall to the ground, and they feed on the cambium layer as well as the gum that is produced as a result of their own injury to the tree. Trees are thus frequently girdled for a distance of several inches.

Much of the ant injury may be prevented by careful planting and proper irrigation practice to prevent the trees from exuding gum, which is often the original attraction for the ant. Tree protectors favor the attacks of the fire ant because some of these protectors, such as black paper, sometimes cause gumming; they also afford shelter for the ants and obscure the injury so that it is not detected by the grower. Whitewash may take the place of the protectors.

Sodium fluoride, as contained in some of the ant powders, will furnish temporary relief, as well as calcium cyanide placed on the ground a few inches from the tree.

GRAY ANT, *FORMICA CINEREA* VAR. *NEOCINEREA* WHEELER

The gray ant is gray in color and larger than the other species, being about $\frac{1}{4}$ inch long. It is one of the native species that has been driven out of the territory occupied by the Argentine species, but has reappeared when eradication campaigns have been carried on against the latter species.

Double the amount of poison (sodium arsenite) in the Argentine-ant-poison formula (page 64) has proved fairly satisfactory for the control of the gray ant.

CONTROL OF CITRUS SCALE INSECTS

For the discussion of the control of citrus pests other than scale insects, see the general discussion of the particular pest.

RESISTANCE OR TOLERANCE OF CERTAIN SCALE INSECTS TO. HYDROCYANIC-ACID FUMIGATION

In any discussion of the control of citrus-infesting scale insects in California, the question of their resistance or tolerance to hydrocyanic acid must first be taken into consideration. Previous to about 1912 or 1913, there had been no serious complaint about unsatisfactory results from fumigation. Since that time fumigation for the red and black scales, and more recently for the citricola, in certain areas (fig. 42) has not effectively controlled these scales. Such resistant areas for the red scale now include sections about Arlington and Corona, in Riverside County; most of the foothill lemon areas in Orange County; and East Whittier, North Whittier Heights, and certain small areas around Glendora, Charter Oak, Covina, and elsewhere in Los Angeles County.

The black-scale-resistant area includes most of the eastern part of Los Angeles County and the western part of San Bernardino County.

The citricola scale was very satisfactorily controlled by early-season fumigation throughout the area where it occurs until four or five years ago, when unsatisfactory results were noted in a certain small area south of Riverside. This particular area has now increased and there are other areas near Highgrove in Riverside County, and also in portions of San Bernardino County. Fumigation for this scale was formerly so dependable that fumigators in Tulare County guaranteed the

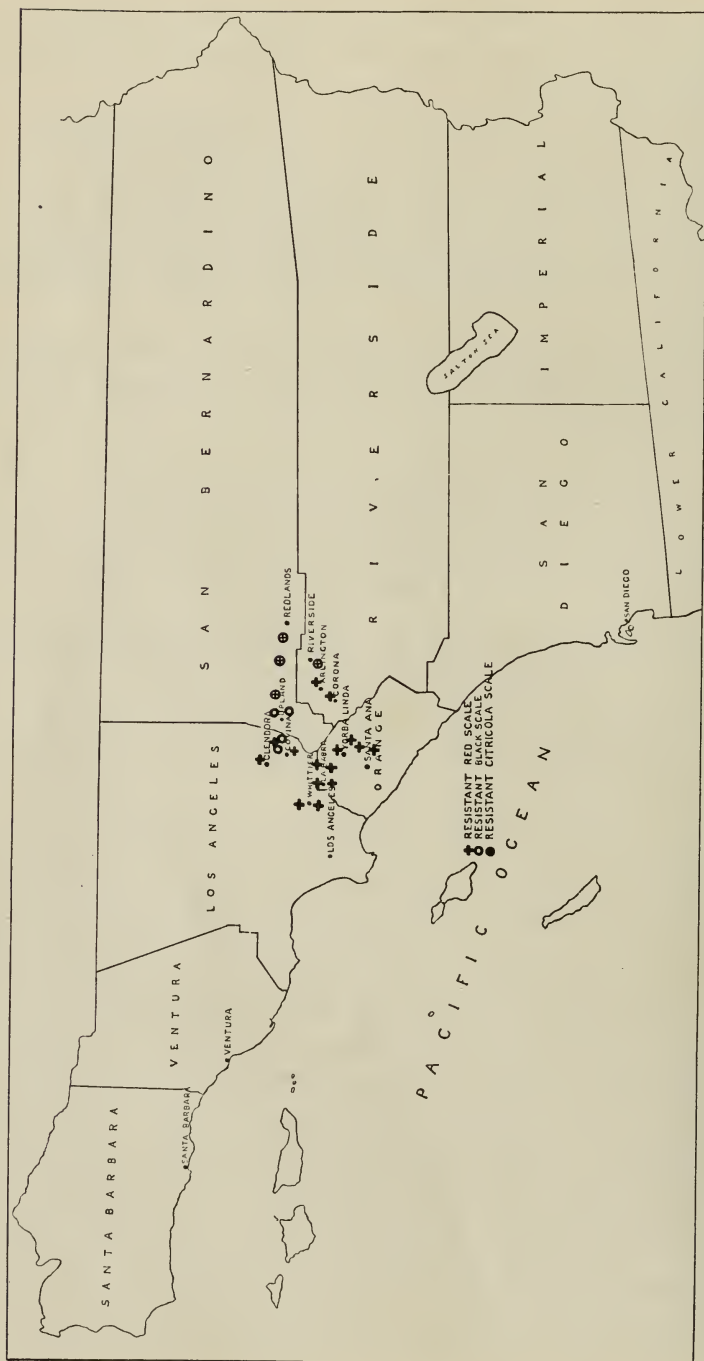


Fig. 42.—Map showing areas where the red, black, and citricola scales have acquired a considerable tolerance to hydrocyanic-acid gas fumigation.

results. Recently, in the resistant areas, even with an increased dosage, cases have been observed where from 20 to 40 per cent of the young scales survived the fumigation.

As a result of this greatly increased fumigation tolerance of the most serious citrus scale insects, the program of control has been materially changed, and the results of control measures have been much less satisfactory than they were before fumigation in certain areas failed to give effective results. This, more than any other one factor, has accounted for the greatly increased use of oil sprays. The unarmored scales, such as the black and citricola, may be satisfactorily controlled by spraying and, since the lighter oils will kill them, there is little serious effect on the trees. In the case of the armored scales, such as the red, yellow, and purple, spraying even with a heavy oil is not very satisfactory; and, where the red scale has become resistant to fumigation, the problem of control is particularly difficult.

COMBINATION TREATMENT

Where the red scale has become resistant to fumigation, both spraying and fumigation are resorted to, particularly on lemons. This constitutes what will be referred to later as the combination treatment. The heavier oil sprays will kill most of the red scale that the spray reaches on the fruit and foliage, but on the old wood many of the scales survive. On the other hand, fumigation kills most effectively on the twigs and branches and least on the fruit, particularly on the outside fruit next to the tent, where such fruits are most likely to be reached by the spray. Consequently, these two treatments are complementary, so far as the results on the scales are concerned, and in addition the spray controls the red spider so that an additional treatment for this pest is unnecessary. The spray also seems to loosen somewhat the attachment of the scale to the plant and there may be also a slight effect on the waxy covering by the oil, thus permitting the gas to reach the insect more readily. For this reason, and also because, in some cases at least, the oil has some protective effect on the tree, the preference is for the fumigation to follow the spray.

The work to date indicates a slight advantage in an interval between fumigation and spraying of 10 to 15 days; it has varied from a week to 8 months. The spray may also be applied in August or September and followed by a winter fumigation. When the fumigation is postponed for a few months, some of the benefits desired from giving the two treatments at short intervals are lost, but the better effect of the winter fumigation tends to balance such loss.

RED SCALE IN NONRESISTANT AREAS

Since the red scale is not effectively controlled by oil sprays, particularly on the old wood, fumigation is the recommended treatment. An 18-cc schedule,⁸ or higher, should be used on oranges, unless in certain of the coastal areas there is involved too much risk to the tree; and a 20-cc schedule, or higher, on lemons. In the interior areas, a 20-cc, and later in the season a 22-cc schedule, may be used. On lemons it is possible to go as high as 22 or 24 cc in most of the areas, if this schedule seems necessary to give satisfactory results. The fumigation season may extend from July to February, or up to the time of blossoming. Later fumigation on lemons may be carried on with good results on the scales, but very late fumigation (April and May) sometimes appears to inhibit the set of fruit. In Orange County, winter fumigation is preferred on both oranges and lemons and for both the resistant and nonresistant red scale. Investigations have shown that the results from winter fumigation carry through the following summer better than does the fall fumigation. But, in cases of heavy infestation, the fumigation cannot be postponed as late as the winter season.

RED SCALE IN RESISTANT AREAS

For the location of the resistant areas of the red scale, see figure 42 and discussion on page 65.

On oranges, fumigation is sometimes sufficient; but, in heavy and persistent infestations, a 1½ to 2 per cent medium or light-medium oil (grades 3 and 4) spray should be applied in August or September, followed by a fumigation with a schedule of 18 or 20 cc within a week or two, or postponed until winter.

On lemons, a 2 per cent heavy oil (grade 5), or 2 to 2½ per cent medium oil (grade 4), plus a fumigation with 22 to 24 cc, is recommended in all cases where fumigation alone has been found unsatisfactory. Our investigations have shown that a higher degree of control by fumigation has been secured in the winter or early spring, but work at this season is limited on account of heaters, covercrops, and unfavorable weather. The reason winter fumigation is preferred is that higher schedules may be used with safety to the tree, and better results on the scales are secured at this time, partly because there are fewer of the resistant stages present, and because the scales themselves seem to be less vigorous and hence more easily killed. Fumigation in the winter, using a 26-cc schedule on lemons, has often given satisfactory results in the Riverside district. The spray for the combination treatment is applied chiefly in

⁸ See pages 75-76 for explanation of schedules.

August, September, or early October. Fumigation may follow the spray from a few days to several weeks, or it may be delayed until winter or early spring.

It has already been stated that the scales that are most likely to survive the fumigation are on the fruit, and particularly on the fruits on the outside of the tree. The stage that is most likely to survive the fumigation is the second molt, but many in the mature and young-producing stage will be found alive after commercial fumigation with a 24-cc schedule, both on the inside and on the outside of the tree. If it were possible to kill all the scales except those in the second molt, a second fumigation within 1 to 3 weeks would be practicable. But, since many in the mature stage also survive, there would still be scales in this stage at the time of the second fumigation from 1 to 3 weeks later.

Work on the resistant red scale indicates that a spray followed by a fumigation gives a higher degree of control than two fumigations. Usually the red spider is also a factor and the spray controls this pest at the same time. The combination treatment is also less expensive. Experiments under field conditions in 15 lemon groves during the past year, where five different spray applications were made and two different schedules of fumigation (22 cc and 24 cc) were made at various intervals, have shown that it is possible to secure a high degree of control at the time of treatment. But, on account of the heavy population in many groves and the favorable conditions of the past few years for the development of the scale, the population builds up rapidly again, particularly during the following summer and early fall.

YELLOW SCALE

The yellow scale, being similar to the red, has been controlled thus far by fumigation. In the interior sections, where the yellow is most prevalent, a 22-cc schedule should be used. Where treatment is necessary in the coastal area, a schedule as high as safety to the tree will permit should be employed, preferably not lower than an 18-cc schedule. Because the yellow scale is not found on the wood in any numbers, a higher degree of control by spraying may be expected with the yellow scale than is the case with the red.

PURPLE SCALE

For purple scale, fumigation in July, August, September, or October is recommended. September is the preferred month. Sometimes July work is desirable in Orange County because of the black scale, which may be in condition for treatment at this time. The purple scale is

usually in good condition for treatment in October, but there is greater risk of injury during this month. There is usually a rather pronounced hatch of the purple scale in September and October, which is indicated by a fuzziness due to the coarse entangling threads that are secreted by the young scales. For a heavy and persistent infestation of the purple scale, a $1\frac{2}{3}$ per cent light-medium or medium oil (grades 3 and 4) on oranges, or a $1\frac{2}{3}$ per cent heavy oil (grade 5) on lemons, followed by a fumigation, should be used; the treatments should be made in August, September, or October. As the eggs are difficult to kill in cold weather, winter fumigation is less satisfactory unless a higher schedule can be used. For fall fumigation, an 18-cc schedule, or higher, should be used, but it may be necessary to drop to a 16-cc schedule in Orange County on oranges.

BLACK SCALE IN NONRESISTANT INTERIOR AREAS

For the nonresistant black scale, generally a fumigation (18 to 22-cc schedule) July to February, is preferable, particularly in the areas where the red spider is not an important factor, because the control may extend over a 2-year period. Spraying with $1\frac{2}{3}$ per cent of light or light-medium oil (grades 1 and 2) will also control the black scale satisfactorily, but a treatment each year is likely to be necessary.

BLACK SCALE IN NONRESISTANT, IRREGULAR HATCH, COASTAL AND INTERMEDIATE AREAS

In general, a fumigation is preferred at a time when the hatch is completed, which may be in July and sometimes in early August, or from December to the latter part of February.

If the black scale is in the proper stage for treatment in the summer or early fall, a light-medium (grade 3) oil spray may be applied in July, August, and September.

BLACK SCALE IN RESISTANT AREAS

The black scale is resistant in parts of eastern Los Angeles and western San Bernardino counties.

Spraying with a light-medium oil (grades 2 and 3), $1\frac{1}{2}$ to 2 per cent, in July, August, and September is recommended.

CITRICOLA SCALE IN NONRESISTANT AREAS

The treatment may be either a fumigation (18 to 22-cc schedule) in July, August, and the first half of September, or a $1\frac{1}{2}$ to $1\frac{2}{3}$ per cent light oil (grade 1) during the same period. In Tulare County, where sulfur dusting is employed for the thrips, an additional later application or two has given good control of the citricola scale.

CITRICOLA SCALE IN RESISTANT AREAS

The citricola scale is resistant in certain areas near Riverside and Highgrove in Riverside County, western San Bernardino County, and portions of the Redlands district.

Spray with a light oil or light-medium oil (grades 1 or 2), $1\frac{1}{2}$ to $1\frac{3}{4}$ per cent, in July, August, or September.

TREATMENT FOR COMBINATIONS OF PESTS

Fumigation is recommended where the nonresistant red scale occurs in considerable numbers, either on oranges or on lemons. If the non-resistant black scale occurs with the nonresistant red scale, fumigation will check both. If the red spider also occurs, spraying with a light medium or medium oil (grades 2, 3, and 4) may also be necessary. If the resistant black scale occurs in the above combination, a fumigation will be necessary for the red scale and a spraying will be necessary for both the black scale and the red spider. The black scale should be well controlled by the two treatments.

Where the resistant red scale occurs, it may be sufficiently checked in some cases by fumigation, particularly in the interior sections where high schedules may be used. If the red scale has persisted for a few seasons, in spite of fumigation, then a spray followed by a fumigation will be necessary. A light-medium or medium (grades 3 or 4) oil spray, $1\frac{2}{3}$ per cent, on oranges, and medium or heavy (grades 4 or 5) oil spray, $1\frac{2}{3}$ to 2 per cent, on lemons, should be used and followed by fumigation with an 18 to 22-cc schedule on oranges and a 22 to 24-cc schedule on lemons. This combination treatment should handle any other pest that may be present, including the black and citricola scales (resistant or nonresistant) and the red spider.

Where the purple scale is the major pest and the black scale is also present, which is nonresistant in such areas, fumigate in September, using a 16 to 18-cc schedule on oranges and an 18 to 22-cc schedule on lemons. If the black scale is important and is in condition for treatment in the summer, a fumigation in July has given good control on the black and often on the early hatch of the purple which occurs in June.

Where the purple scale is spotted on only a few trees, and the black scale is not in condition for treatment in the summer, fumigate the purple-scale-infested trees in September, and the entire grove in the winter (December to February).

Where the combination treatment seems desirable for a heavy infestation of the purple scale, and the black scale is also present, the treat-

ment should be timed, if possible, according to the condition of the black scale, since the combination will take care of all stages of the purple scale but is not effective on the large, egg-laying stages of the black scale.

Where a light infestation of citricola scale occurs together with the citrus thrips, the control suggested for the thrips on page 24 will keep them both in check. If the citricola scale infestation is heavy, an early fumigation (July to September 15), using a schedule of 20 to 22 cc, or spraying with light or light-medium oil (grades 1 or 2), $1\frac{1}{2}$ to $1\frac{2}{3}$ per cent, at the same season, may be employed.

FUMIGATION

Fumigation with hydrocyanic acid originated in California in 1886, and ever since its adoption it has been recognized as one of the dependable methods for the control of scale insects on citrus trees. Shortly after the beginning of its use, the method of generation of the gas was by the so-called "pot system," which consisted of placing water (3 parts by volume), sulfuric acid (1 part by volume), and potassium cyanide⁹ (1 part by weight) in an earthenware vessel beneath each tented tree. This method was in use until about 1913, when it was replaced by the so-called "machine-generation" method. The machine consisted of a generating and supply chamber mounted on two wheels and drawn by a horse. In the generating chamber was placed sulfuric acid and water, to which was added the required amount of cyanide solution for each tree. The gas from the cyanide solution was evolved almost instantaneously and it was forced by its own pressure through a hose to the tented tree. In 1916, the first tests were made with liquid hydrocyanic acid (HCN), and the method utilizing HCN in liquid form quickly came into very general use, and from 1918 to date has been used almost exclusively.

Liquid hydrocyanic acid is manufactured at a central plant and is carried to the orchards in drums of 80 and 100 pounds' capacity. From these drums it is transferred into so-called applicators, which measure the schedule and deliver it under the tree through nozzles which convert the liquid into a fine spray that immediately transforms into a gas. Liquid HCN is a colorless liquid, boiling at 80° F and having a specific gravity of 0.70 at a temperature of 65° F. It is very volatile and must be kept at fairly low temperatures to be safe in handling. During hot weather the drums of HCN are kept in a cool place where there is air

⁹ After 1909, sodium cyanide was used in the proportions of 2 parts by volume of water, $1\frac{1}{2}$ parts by volume of acid, and 1 part by weight of cyanide (51-52 per cent cyanogen).

circulation, and are usually covered with sacking over which water drips. When the HCN is transported by truck during the warmest weather, it is packed in ice as an additional safeguard.

EQUIPMENT

Tents.—The tenting materials in use at the present time are of 7 or 8-ounce United States army duck, and 6½-ounce special drill. Usually the special drill is limited to the wings of the tent; and the center, over which the most of the wear occurs, is made of the duck.

The tents are octagonal sheets of different diameters, the most common sizes being 36, 45, 48, 50, and 55 feet. In purchasing tents for a particular planting, the normal growth of the trees for the next four or five years is taken into consideration. For trees up to 10 feet in height, 36 to 40-foot tents are used; for trees up to 15 feet in height, 40 to 45-foot tents; and from 16 to 21 feet in height, 45 to 55-foot tents are used. The number of tents in an outfit range from 30 to 70 or more.

The tents are marked with three parallel lines of figures, starting at 5 or 6 feet from the center of the tent and running toward the opposite edges. By reading these figures on the tent, where they come to the ground on opposite sides of the tree, the distance over is determined. The distance around is secured by means of a tape. When the distance around and over is known, a dosage table, such as table 1, is used to determine the number of units of HCN the tree should receive.

Poles and Derricks.—Two poles, of a diameter of 2 to 2¼ inches, and 14, 16, or 18 feet long, are used for pulling the tents over the trees. Near one end of the poles a rope is attached, which extends about 3 feet beyond the other end. A ring on the tent is placed over the end to which the rope is attached; the other end is sharpened so that the pole will stick into the ground while it is raised, with the tent attached, by means of the rope. In the case of very large trees derricks are used.

PROCEDURE

Fumigation is carried on by cooperative pest control associations, local citrus associations, commercial operators, or private owners.

Directions for the work are determined largely by the respective agricultural commissioners in the different counties. These officials issue licenses to properly qualified operators; determine when treatment is necessary; indicate the range of temperatures, and, more or less, the humidity at which the work should be carried on; advise as to the schedule and other general regulations of the work; inspect the equipment; and finally check the results.

TABLE 1

UNITS OF LIQUID HYDROCYANIC ACID (HCN) REQUIRED TO FUMIGATE CITRUS TREES
OF DIFFERENT SIZES WHEN 7 OR 8-OUNCE U. S. ARMY DUCK IS
USED FOR TENTING MATERIAL*

12†	14	16	18	20	22	24	26	28	30	32	34
10-2	10-2	10-3	10-3	10-3	12-4	12-4	14-5	16-5	16-5	18-6	18-6
12-3	12-3	12-3	12-4	12-4	14-4	14-5	16-5	18-6	18-6	20-6	20-7
14-3	14-3	14-4	14-4	14-4	16-5	16-5	18-5	20-6	20-6	22-7	22-7
16-4	16-4	16-4	16-4	16-5	18-5	18-5	20-6	22-6	22-7	24-7	24-7
18-4	18-4	18-4	18-5	18-5	20-5	20-6	22-6	24-7	24-7	26-7	26-8
				20-5	22-6	22-6	24-6	26-7	26-7	28-8	28-8
				22-5	24-6	24-6	26-7	28-7	28-7	30-8	30-9
				24-6					30-8	32-9	32-10
											34-10
											36-11
36	38	40	42	44	46	48	50	52	54	56	
18-6	20-7	20-7	20-7	22-8	22-8	26-10	26-11	30-13	30-14	30-14	
20-7	22-7	22-7	22-7	24-9	24-9	28-11	28-12	32-15	32-15	32-15	
22-7	24-8	24-8	24-8	26-10	26-10	30-12	30-13	34-16	34-17	34-17	
24-8	26-9	26-9	26-9	28-11	28-11	32-14	32-14	36-17	36-18	36-18	
26-8	28-9	28-10	28-10	30-12	30-12	34-15	34-15	38-18	38-19	38-20	
28-9	30-10	30-11	30-11	32-13	32-13	36-16	36-17	40-20	40-21	40-21	
30-10	32-11	32-12	32-12	34-14	34-14	38-17	38-18	42-21	42-22	42-23	
32-10	34-12	34-13	34-13	36-15	36-15	40-18	40-19	44-23	44-23	44-24	
34-11	36-13	36-14	36-14	38-16	38-17	42-20	42-21	46-24	46-25	46-26	
36-12	38-14	38-14	38-15	40-17	40-18	44-21	44-22	48-25	48-26	48-27	
38-13			40-16	42-18	42-19	46-23	46-23	50-26	50-27	50-28	
					44-20		48-24			52-30	
							50-25				
58	60	62	64	66	68	70	72	74	76	78	
30-14	32-16	34-18	34-18	36-21	40-25	40-25	42-28	44-30	46-33	48-36	
32-16	34-18	36-20	36-20	38-22	42-26	42-27	44-30	46-32	48-35	50-38	
34-17	36-19	38-21	38-22	40-24	44-28	44-29	46-32	48-34	50-37	52-40	
36-19	38-21	40-23	40-24	42-26	46-30	46-31	48-34	50-36	52-39	54-42	
38-20	40-22	42-25	42-25	44-28	48-32	48-33	50-36	52-38	54-41	56-44	
40-22	42-24	44-27	44-27	46-29	50-34	50-35	52-38	54-40	56-43	58-47	
42-23	44-26	46-28	46-29	48-31	52-36	52-37	54-40	56-42	58-45		
44-25	46-27	48-30	48-31	50-33	54-38	54-39	56-42	58-44			
46-27	48-29	50-31	50-32	52-35	56-40	56-41	58-43				
48-28	50-30	52-33	52-34	54-37	58-41	58-42					
50-30	52-32	54-35	54-36	56-39							
52-31	54-33	56-36	56-38	58-40							
54-32	56-35	58-38	58-39								
	58-36										

* The arrangement of this dosage table is similar to the one used in: Woglum, R. S. Fumigation of citrus trees for control of insect pests. U. S. Dept. Agr. Farmers' Bul. 1321:30-31. 1923. This particular arrangement is used in order that the dosage may be transferred to the measuring tape if desired. Many fumigators now depend upon the dosage as given on the tape instead of having it on a separate chart. An illustration of a short section of the tape carrying the dosage is as follows:

12 ² ₂	14 ² ₂	16 ² ₂	18 ² ₂	20 ² ₂	22 ² ₂	24 ² ₂	26 ² ₂	28 ² ₂	30 ² ₂	32 ² ₂	34 ² ₂
10 ² ₂	12 ² ₂	14 ² ₂	16 ² ₂	18 ² ₂	20 ² ₂	22 ² ₂	24 ² ₂	26 ² ₂	28 ² ₂	30 ² ₂	32 ² ₂

† Figures across top of columns represent distance around in feet. Figures on left side of columns represent distance over in feet. Italic figures on right side of columns represent dosage in units of HCN. The unit varies from 14 cc to 26 cc according to the schedule required.

At the present time the gas is applied to the tree from two different types of applicators: one the ordinary applicator which uses so-called "cold gas" (the gas as it comes from the plant, without heating); and the other applicator, known as the "vaporizer," which heats the gas by means of a water jacket heated over a gas burner. This is the so-called "hot gas" method of generation, which is used during the colder part of the fumigating season. It results in more rapid diffusion of the gas in the tent and is desirable when fumigation is carried on at the lower temperatures (below 50° F) or in daylight. The applicators are owned and serviced by the companies that furnish the HCN, and are simply loaned to the fumigators.

The temperature range at which fumigation is carried is from 40° to 80° or 85° F, most of the work being between 50° and 70°; in sections along the coast, 70° or 75° is considered the maximum temperature, whereas in the interior fumigation may begin at a temperature of 80° to 85°.

The relative humidity cannot be very accurately indicated for the practical fumigator. When visible moisture appears on the trees, and tents begin to feel moist, it is the most practical indication of the time to stop fumigation. With high humidity the pores of the tents are decreased by the expansion of the fabric, and hence the tents allow less leakage of gas. Also when the tents are wet they pick up particles of sand and grit, which when pulled over the outside of fruits cause abrasions, and it is here that injury is most likely to occur.

The schedule given depends upon the scale which is to receive treatment, the variety of the tree, and the locality where the fumigation is carried on. Under the heading "Control of Citrus Scale Insects" were indicated the different schedules for use under different conditions. These schedules are indicated by the number of cubic centimeters in a so-called unit. Before liquid HCN came into use, the schedules called for a certain number of ounces of sodium cyanide, according to the distance over and around the tree. This meant roughly that 1 ounce of sodium cyanide was required for each 100 cubic feet of space for an ordinary-sized tree. For smaller trees, the schedule called for more than 1 ounce for each 100 cubic feet; while on larger trees less than 1 ounce per 100 cubic feet was required. This variation in the amount per unit of volume is due to the fact that in a smaller tree there is more tent surface in relation to the volume than is the case with a larger tree; the tent surface is one of the factors that govern the schedule, because the greater the tent surface the greater is the leakage of gas. When liquid HCN came into use, this same general schedule was retained; but, in-

stead of indicating the schedule in ounces, the term "unit" was applied as being the most convenient term.

In making a comparison of liquid HCN with the older methods¹⁰ where ounces of cyanide were used, the writer determined that 1 ounce of sodium cyanide (51–52 per cent cyanogen) was equivalent to 20 cc of liquid HCN of 97 per cent purity. Instead of having different schedules prepared according to the dosage to be given to a grove with the old system of using ounces of cyanide, when the liquid HCN came into use a single schedule with some modification was adopted and the variation made in the unit. Consequently, the applicators for the delivery of HCN under the tent can be set to deliver 14 cc, 16 cc, 18 cc, 20 cc, 22 cc, or 24 cc for each unit, according to the dosage which should be used under the different conditions. If the tree called for 10 ounces of sodium cyanide under the old system, the same tree under the new system of liquid HCN would call for 10 units of liquid HCN; and if 14 cc was the amount of the unit, that particular tree would be given 140 cc. If the amount of the unit was 20 cc, the amount of liquid HCN would be 200 cc, etc. There are approximately 640 to 650 cc in 1 pound of liquid HCN, according to the temperature and the degree of purity.

¹⁰ Before liquid HCN came into general use, it was customary to refer to schedules on a percentage basis, such as "100 per cent schedule," a "75 per cent schedule," etc. The 100 per cent schedule represented 1 ounce of sodium cyanide to each 100 cubic feet of space for an average-sized tree, and it was supposed to be about as high a schedule as could be generally used with safety to the tree. When fumigation started in Tulare County, in 1915, a 110 per cent schedule was used, and later a 120 per cent schedule there and elsewhere. The schedules called for a different number of ounces of sodium cyanide for a tree of a particular size. When liquid HCN came into use, instead of having different schedules, the variation in schedules was made in the unit, the term substituted for ounces in the old schedules. Therefore, reference to the different schedules should now be made on the value of the unit, as a "14-cc schedule," a "20-cc schedule," etc., and reference to schedules on the percentage basis, as "100 per cent schedule," and "88 per cent schedule," is antiquated and should no longer be used.

Since 20 cc of liquid HCN (97 per cent purity, 70° F) represents the same amount of HCN as is evolved under commercial conditions from 1 ounce of sodium cyanide (51–52 per cent cyanogen) the 20-cc schedule should have been adopted as the one corresponding to the old 100 per cent schedule. But when liquid HCN came into use the old 100 per cent schedule calling for ounces was raised somewhat (the reason not being apparent) when the ounces were changed to units for use with the liquid HCN method. For example, a tree calling for 9 ounces of sodium cyanide under the old 100 per cent schedule would call for 9 units of liquid HCN, and, if 20 cc represents the unit, the tree would receive 180 cc of liquid, or an amount equal to the old 100 per cent schedule. But the modified schedule called for 10 units instead of 9, and so the unit value was reduced from 20 cc to 18 cc, and the latter when multiplied by 10 also gives 180 cc, which corresponds to the old 100 per cent schedule. By such manipulations, therefore, it has come about that in commercial citrus fumigation an 18-cc schedule is generally considered as corresponding to a 100 per cent schedule. Since the percentage schedules still linger in a few places, it has been necessary to explain the relation between the "cc" schedules and the "percentage" schedules, and how they originated.

The amount of HCN used on any block of trees may be determined by adding the total number of units given to all of the trees and multiplying this by the number of cubic centimeters in the schedule used. That is, in a 20-cc schedule the total number of units in the orchard, multiplied by 20 cc, would give the total number of cubic centimeters used in the grove, and from this the number of pounds may be determined by dividing by 640, the number of cubic centimeters in 1 pound of liquid HCN.¹¹

The number of tents used in an outfit depends upon the size of the orchard to be treated. If the rows in a particular orchard are 20 trees long, 20 tents would be placed along one side of the grove and 20 additional tents along about the center row of the grove (except in large groves), using 40 tents in all, and in pulling and charging the tents a round trip is made, i.e., the operators go up the first row of tents and back the second row.

The period the tents are left on the trees is 50 minutes to 1 hour. At the end of that period the tent is pulled from the first tree onto the next row, and so on, finishing on the last tree of the second row of tents.

The usual crew consists of four men: two to pull tents, one to follow up with the measuring and kicking in the edges of the tent, and the fourth to deliver the charge to the tent as called out by the man measuring the tree immediately ahead. In cases of very large trees, four men are used to pull the tents.

COST

The cost of the fumigation is dependent upon the size of the tree and is usually divided into coverage and the cost of the HCN used. The coverage includes the cost of labor, wear and tear on the tent, interest on investment, depreciation, etc. In contract fumigation the fumigator agrees to cover the trees for a certain amount, the cost of the HCN (depending upon the amount used) being added. The cost of the HCN is about one-half of the total cost of the operation, and the coverage cost the other half. On an average, the cost of fumigating in California is somewhere near 40 cents a tree, 20 cents representing the cost of the HCN and 20 cents the coverage.

PRECAUTIONS TO AVOID INJURY

There are a number of precautions to be taken in fumigation procedure in order to avoid injury to the tree and at the same time to be effective in killing the scales. In the first place, the season of the year

¹¹ The number of cubic centimeters in a pound of liquid HCN varies with the purity and with the temperature: 640 cc = 1 pound liquid HCN of 96 per cent purity and at 60° F.

must be considered. Generally speaking, the fumigating season begins about the first of July and continues into the following March. Fumigation cannot be practiced from the time the oranges set until they are about the size of walnuts, without involving undue risk to the fruits.

Navel oranges are further advanced than the Valencias, so that at the beginning of the fumigation season, where fruit of both varieties is on the trees, the first week or two fumigation is usually carried on for the navels. The navel and Valencia trees are about equally resistant; however, most of the Valencias occur in the coastal area, where there is more danger of injury than in the interior. The ordinary dosage cannot be used on such varieties as the St. Michael and Homosassa, the fruits of which are very susceptible to injury.

The lemon is the most resistant of all of the citrus varieties. The fumigating season for the lemon is longer than that for the orange, because there is no particular time when all of the young fruits appear, as is the case with the orange, and because lemon fruits of all ages are more resistant to the gas than are small oranges. So far as the tree is concerned, the lemon may be fumigated at almost any time during the year.

On the other hand, the insect may definitely limit the time of fumigation. The black scale is not effectively killed by fumigation except when in the younger stages; consequently fumigation, to be effective, must be restricted to a time when these stages occur. The citricola scale is still more narrowly restricted as to time, since it becomes resistant after about the middle of September, although it is still quite small for the following few months. The red scale, on the other hand, may be found in practically all stages at any season of the year; consequently the time, as far as the scale is concerned (at least in the nonresistant areas) is less important than with any other scale. The purple scale may also be found in various stages in different seasons of the year, although there is a more or less definite hatch in August and September. For this reason fumigation can best be carried on for this scale at that particular season, and also because the eggs of this scale are difficult to kill during the colder weather of winter.

The soil in the orchard to be fumigated should be well cultivated, in order that the tents may lie in close contact with the ground. Fumigation should be avoided as far as possible when there are covercrops, or when the ground is furrowed for irrigation. Fumigation too soon after irrigation is likely to result in injury to the trees. It is not desirable to have the trees suffering from lack of water, but fumigation can be carried on with much greater safety when the soil is too dry than when it is too wet.

The cycles of growth of the trees are also related to fumigation injury. The young growth is most susceptible to injury, and when much of this is present more damage will be done. Of the different cycles of growth, the spring cycle seems to be rather more resistant than the others. Sometimes trees become unusually susceptible, particularly in some of the coastal areas, during the month of October, and fumigation may well be suspended for a time during that season.

In addition to the weather conditions already mentioned, fumigation should not be carried on when the humidity is extremely low, as it is during the so-called northerners. Wind is very important in connection with fumigation results; since the results are likely to be greatly impaired if there is sufficient wind to move the tents to any extent. The tree is much more resistant to HCN gas in darkness than in sunlight, especially in strong sunlight during the summer season. On the other hand, during the winter season fumigation may be carried on satisfactorily during a considerable part of the day, starting particularly in the afternoon or early evening.

Bordeaux mixture (either as a spray or in the form of a paste) applied on the larger branches up beyond the crotch of the tree, or on the foliage, should not be followed by fumigation, unless the winter rains have occurred in the meantime. The application of bordeaux paste, limited to the trunk only and not extending beyond the crotch, may be followed by fumigation without any particular hazard. Injury to the tree has occurred from the application of bordeaux followed by fumigation after a period of 5 or 6 months. Bordeaux should, therefore, be applied after rather than before the fumigation, or the fumigation should be postponed for about a year after the application of the bordeaux.

OIL SPRAYS^{12, 13}

TYPES OF OIL SPRAYS

The various types of oil sprays may be grouped into three classes: miscible oils, oil emulsions, and tank mixtures. A miscible oil is a petroleum oil in which is dissolved an emulsifying substance such as a sulfonated vegetable oil or a soap of cresylic acid or naphthenic acid. When diluted with water it forms a milk-like spray mixture. The oil globules are very small and, owing to this fact, they float out very slowly and the mixture is characterized by a high degree of stability.

¹² By Ralph H. Smith, Entomologist in the Citrus Experiment Station.

¹³ Readers desiring further information on oil sprays, and especially on the tank-mixture method, may consult Bulletin 527 of the California Agricultural Experiment Station.

The emulsifying substances are rather toxic to plants, and this, in part, accounts for the spotting and burning of oranges which sometimes results from the use of miscible oil sprays. Miscible oils have been used in combination with lime-sulfur in spraying for citricola scale and thrips in the San Joaquin Valley, and for citricola and black scales in navel districts of the southern counties.

Oil emulsions are made by dissolving a small amount of emulsifier, such as potassium fish-oil soap, ammonium caseinate, or saponine in one part of water, stirring in four parts of petroleum oil, and violently agitating the mixture or forcing it through a spray nozzle or a colloid mill. This process breaks the mass of oil into innumerable globules and causes the mixture to become thick, in which condition it will remain stable for a long period. High temperature and long-continued vibration, such as may be produced by transportation by train and truck, tend to de-emulsify the oil. The emulsion may be readily diluted with water, but the oil globules are relatively large and float out rather rapidly unless the mixture is agitated.

With tank-mixture spray, the oil and emulsifier are added separately to the water in the spray tank, and a uniform mixture is produced and maintained by proper agitation. The oil globules in the tank are much larger than those occurring in emulsions, but after passing through the spray nozzle they have practically the same size as those in emulsions.

FACTORS RELATING TO EFFECTIVENESS AND SAFETY OF OIL SPRAYS

The insecticidal efficiency of oil sprays and the effect of oil sprays on trees, as far as the spray is concerned, are governed by the purity of the oil, the heaviness of the oil, and the amount of oil deposited on the tree.

Purity.—Petroleum oils are composed of two principal classes of chemical compounds: (1) saturated hydrocarbons, and (2) unsaturated and aromatic hydrocarbons. The compounds of the second class are decidedly toxic to plants. They are regarded as impurities and their removal constitutes an important phase of the process of refining petroleum. They combine readily with strong sulfuric acid, and the purity of spray oils is expressed in terms of the percentage of oil that remains unchanged when treated with sulfuric acid. For example, an oil having a sulfonation of 90 per cent is one containing 10 per cent of the impurities mentioned; that is, 90 per cent of the oil will remain unchanged when treated with strong sulfuric acid. Information ob-

tained by experimentation and observation over a period of several years indicates that in the case of light and light-medium oils a sulfonation of 90 to 92 per cent is satisfactory. In the case of medium and heavy oils, the factor of injury presents a more difficult problem. Because of this fact it is recommended that oils falling in the medium grade have a sulfonation of not less than 93 per cent and those falling in the heavy grade have a sulfonation of not less than 95 per cent.

TABLE 2*

DISTILLATION RANGES OF THE OILS CONTAINED IN TWO BRANDS OF "LIGHT" EMULSIONS, AND THE SERIES OF FIVE GRADES OF OILS USED EXTENSIVELY IN TANK-MIXTURE SPRAYS DURING 1931

Degrees Fahrenheit	Emulsions		Spray oils				
	Brand No. 1	Brand No. 2	Grade No. 1	Grade No. 2	Grade No. 3	Grade No. 4	Grade No. 5
	Per cent distilled						
550.....	6	33	3	1	0	0	0
575.....	24	43	21	14	9	3	1
600.....	48	54	46	38	27	13	4
625.....	67	62	70	59	50	36	19
650.....	78	72	86	75	69	56	43
675.....	90+	77	90+	86	82	73	59
700.....	....	85	....	90+	89	84	77
725.....	....	90+	....	....	90+	90+	86
750.....	....	....	....	....	....	....	90+

* From: Smith, Ralph H. The tank-mixture method of using oil spray. California Agr. Exp. Sta. Bul. 527: 15; table 1. 1932.

Heaviness.—Spray oils have been classified as light, light-medium, medium, and heavy, on the basis of viscosity and also on the basis of distillation range. Viscosity pertains to the flowing quality of an oil. It is expressed in terms of the number of seconds required for 60 cubic centimeters at a temperature of 100° F to flow through a small orifice in an instrument known as the Saybolt Universal viscosimeter. Distillation range indicates the minimum and maximum temperatures between which the distillation of an oil takes place and the percentage of oil distilling at points within the range. Distillation range affords a very dependable index to the volatility of oils. Since the insecticidal value of oils and the deleterious action of oils on citrus trees are proportional to the volatility of the oils but are not necessarily related to the viscosity of the oils, it follows that the grading of oils according to heaviness should be made on the basis of distillation range. In table 2 are given examples of the distillation ranges of the oil contained in two brands of "light" emulsions and the distillation ranges of a series of five spray

oils. The oil in brand No. 1 appears to be a particularly narrow-cut oil and is a very desirable type for a light oil. The oil in brand No. 2 may be regarded as an exceptionally wide-cut oil but the more probable interpretation is that it was produced by blending kerosene with a heavy oil like grade No. 5. It is not a suitable type because a large percentage of it distills below 550 degrees and is too light to be of much value in the control of scale insects and, furthermore, the portion distilling above 675 degrees is heavier than is necessary or desirable for doing the work properly required of a light oil. Spray oils No. 1 to No. 5 inclusive, represent a gradual increase in heaviness and afford a series of grades well adapted to meeting the various requirements of citrus spraying.

Amount of Oil Deposited on the Tree.—Investigation has shown that the deposit of oil tends to build up as spray is applied in excess of the quantity required to effect an initial covering and that the amount deposited, as well as the building-up tendency, may vary greatly among brands of emulsions. The oil-depositing quality of a spray is governed largely by the kind and amount of emulsifier contained in the spray. Experiments have indicated that a spray of oil and water, without an emulsifier, ranks highest in efficiency in the control of scale insects; but it also ranks lowest in safety, owing to the excessive amount of oil it may leave on parts of the tree which receive too much spray. In order to effect a coverage of all parts of a tree, drenching quantities of spray must be applied, with the result that some parts will be greatly oversprayed. The safety of the spray can be raised by increasing the amount of emulsifier or spreader, but this results in correspondingly decreasing the insecticidal efficiency of the spray. It seems necessary, therefore, to strike a compromise between safety and insecticidal efficiency. Theoretically, the safety of the spray should be varied according to the heaviness of the oil and the tolerance of the tree, as affected by the variety, season, and district, and, also, according to the degree of thoroughness of the application.

TANK-MIXTURE SPRAY

Tank-mixture spray is the result of an investigation undertaken by the University of California Citrus Experiment Station with the object of aiding in the standardizing of oil sprays and simplifying spraying for pest control. The principal advantage is that it provides the citrus grower with a standard type of spray of known composition at a marked saving in cost. It was approved for general use by the Experiment Station at the beginning of the spray season in 1931. Approximately one-

third of all spraying of citrus trees in the southern counties that year was done with tank-mixture spray.

Oil.—The oil is delivered in 50 and 30-gallon drums, just as it is produced at the refinery. Pending the outcome of experiments in progress, the Citrus Experiment Station will take the position that there is a place for five grades of oil, corresponding to those used during 1931 in tank-mixture spray (table 2). In order to simplify the problem of the grower who desires to obtain an oil of a definite grade, the grades are designated by number, grade 1 being the lightest, and grade 5 the heaviest.

As a general explanation of the grades, it may be stated that refiners produce a light oil of grade 1, and a heavy oil of grade 5, and blend these to make the intermediate grades. In most cases grade 2 contains about 25 per cent heavy oil, grade 3 about 40 per cent, and grade 4 about 60 per cent. The minimum sulfonation of the oils as guaranteed by labels on the drums, is as follows: grades 1 and 2, 90 per cent; grades 3 and 4, 92 per cent; grade 5, 94 per cent. The actual sulfonation may be expected to run 1 per cent higher than that guaranteed. Major refiners and spray firms are prepared to supply oils suitable for these grades.

Grade 1 specifies a rather narrow-cut oil and falls strictly in the light class. It has a wide margin of safety, as regards volatility, and therefore is particularly useful for off-season spraying for red spider and scale insects. It is the preferred grade to use in the interior districts where red spider is not a problem and where impaired blooming and coloring of fruit are important factors of consideration in spraying navel oranges. The dosage recommended for citricola and black scales is $1\frac{1}{2}$ to $1\frac{2}{3}$ per cent. For average conditions of infestation, $1\frac{1}{2}$ per cent is adequate. For winter and spring treatment of red spider a thorough application, using $1\frac{1}{2}$ per cent, has given satisfactory results.

Grade 2 falls in the light-medium class and corresponds to the grade designated "Light-Medium 65" in the recommendations for tank-mixture spray in 1931. Its commercial use that year and the results of experiments indicate that it meets the needs for black-scale and red-spider control in the districts intermediate between coastal and interior. It provides a relatively safe oil for navel oranges in those districts where impaired coloring, rind breakdown, and development of decay have been factors of consideration in the use of oil sprays. Dosage recommended is $1\frac{1}{2}$ to $1\frac{2}{3}$ per cent. For average conditions of infestation, $1\frac{1}{2}$ per cent is adequate.

Grade 3 also falls in the light-medium class. It was used extensively during 1931 in the coastal districts in spraying oranges for red, purple,

and black scales, and red spider. On the whole, the results were very satisfactory, although the control was not so high as was obtained with grade 4. The dosage recommended is $1\frac{1}{2}$ to $1\frac{2}{3}$ per cent.

Grade 4 corresponds to the oils contained in the leading brands of medium emulsions which have been used extensively in spraying oranges in the coastal districts. It will give a higher degree of control of scale insects, particularly red scale, and a more effective hold-over control of red spider than will grade 3. It is the heaviest oil that should be used on orange trees. The dosage recommended is $1\frac{1}{2}$ to $1\frac{2}{3}$ per cent.

Grade 5 is to be used only in spraying lemon trees in the coastal districts for red scale. The dosage may be gauged within limits by the degree of infestation and the degree of control desired, bearing in mind that $1\frac{2}{3}$ per cent of this oil in tank-mixture spray is equal to 2 per cent of the heavy emulsions, which have been widely used for control of this insect. It is estimated that over one-half of all spraying of lemons for red scale in 1931 was done with tank-mixture spray. The prevailing dosage was 2 per cent.

Spreader.—The spreader or emulsifier consists of 1 part powdered blood albumin, and 3 parts fuller's earth. This mixture, known as *powdered blood albumin spreader*, is used at the rate of 4 ounces to 100 gallons of spray. The use of the spreader at this rate gives a spray that is about average in oil-depositing quality, efficiency, and safety. This means that when the proper grade of oil is used at $1\frac{1}{2}$ or $1\frac{2}{3}$ per cent, and the degree of thoroughness of the spray application is average, and the physical condition of the tree is normal, effective control may be obtained without especial risk of excessive fruit-drop, leaf-drop, or other unfavorable effects.

Sprayer Equipment.—In order that the use of tank-mixture spray will be adequately safe, spray tanks are required to have sufficient agitation to produce a uniform mixture within approximately $\frac{1}{2}$ minute after starting the motor. A large proportion of sprayers already meet this requirement. It necessitates an agitator speed of approximately 200 r.p.m. and the use of large-sized agitators.

Directions.—No particular directions need be followed in placing the oil and spreader in the spray tank; but the preferable procedure is to add the oil when starting to fill, and then sift in the spreader. The agitator should be kept running continuously from the time the oil is added until the spray is applied. This requirement eliminates the possibility of the use of imperfect mixtures, and also the possibility of splashing the oil out while hauling the sprayer from the filling station to the point of spraying in the grove.

Cost.—During 1931 the cost of the spreader was 5 cents per 100 gallons of spray (15 cents for the 12-ounce package and 20 cents for the 16-ounce package). The price of the oil delivered to the grove ranged from 22 cents a gallon for grade 1 to 35 cents a gallon for grade 5.

When to Spray.—The favorable period for using oil spray on orange trees is from about July 15 or 20, to about September 15. August is definitely the preferred month. It is generally believed that early spraying may accentuate the "June drop" of green fruit, which normally occurs during June and July. Beginning with about the first of September, there is a gradual increase in the risk of encountering such unfavorable reactions as delayed coloring, impaired blooming, and, in the navel area of Los Angeles County particularly, accentuated rind breakdown, which is associated with rainy weather in winter and spring. In the coastal districts, and perhaps in all districts, there is evidence that orange trees undergo a sort of subnormal physical condition in the fall—October usually being the critical month—when the trees may react unfavorably, and more or less erratically, to pest-control treatments. With oil spraying there may occur pronounced or even excessive leaf-drop and fruit-drop in occasional groves. While rather early spraying is preferred from the standpoint of tree and fruit reaction, late summer spraying may be desirable where red spider is a problem of particular importance.

The combination spray of miscible oil and lime-sulfur is used in the late fall and early winter, November and December particularly.

LIST OF REFERENCES FOR FURTHER READING

The following bibliography includes a selected list of references to the literature for those who wish more detailed information on the subjects discussed in this bulletin. A few references on nematodes, snails, and rodents have been included for those who may be interested in citrus pests other than insects and mites.

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¹⁵ Copies of California Agricultural Experiment Station publications that are out of print will be found on file at most city and county libraries in California.

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